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TRANSPORTATION RESEARCH COMMAND

FORT EUSTIS, VIRGINIA

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AS AD No. 414492

TRECOM TECHNICAL REPORT 63-8

FOR

ALARM SYSTEM APPLICATIONS TO ARMY AIRCRAFT

Automatic Light Aircraft Readiness Monitor

Project 9R89-02-015-16

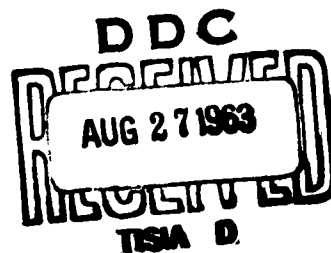
Contract DA 44-177-TC-641

January 1963

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The findings and recommendations contained in this report are those of the contractor and do not necessarily reflect the views of the U. S. Army Mobility Command, the U. S. Army Materiel Command, or the Department of the Army.

HEADQUARTERS
U S ARMY TRANSPORTATION RESEARCH COMMAND
Fort Eustis, Virginia

This report is a discussion of the results of an investigation to determine the feasibility of using an Automatic Light Aircraft Readiness Monitor at the first and second echelons of maintenance. The report also includes discussion of an onboard flight unit.

The report includes data derived from a limited test program and an analysis of these test results.

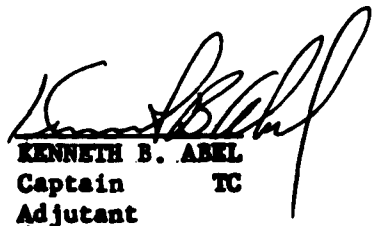
An adequate test program could not be accomplished because amplitudes of vibration, pressure, and temperatures representing or indicating a normally operating aircraft are not known. Go/no-go limits may not be established until the levels indicating normal operation are determined, especially the vibratory and temperature levels.


Therefore, the conclusions expressed by the contractor are not based on proven test results but rather on an indication of feasibility arrived at by review of engineering test data and by applying engineering experience for interpretation.

The recommendations made by the contractor are not concurred in by this Command. This Command recommends that, before any additional work is undertaken in the application of an ALARM system to Army aircraft, a test program be accomplished to establish the normal levels of a go/no-go condition for a specific model aircraft so that the value of an ALARM system may be truly established.

This Command recommends that these tests to establish normal levels be conducted on a late-model helicopter (UH-1B or CH-47A) to expedite future efforts of development required for incorporation of ALARM in the Army system.

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Task 1D141812D18416
(Formerly Task 9R89-02-015-16)
Contract DA 44-177-TC-641
TRECOM Technical Report 63-8
January 1963

Project ALARM
AUTOMATIC LIGHT AIRCRAFT READINESS MONITOR
Applications Report

Prepared by
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for
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FOREWORD

This document, TRECOM Technical Report 63-8, represents a report regarding the application of the developed Automatic Light Aircraft Readiness Monitor system (ALARM) to fixed wing and rotary wing Army light aircraft. The Applications Report is provided in addition to the ALARM Phase II Final Report, published as separate documents (TRECOM Technical Report 63-10, Volumes I, II, and III.)

The ALARM program was conducted by the York Division of The Bendix Corporation for the United States Army Transportation Command; Mr. Christmas A. Malami was the project officer. The over-all operation was under the direct supervision and control of David E. Myers, project engineer, with Donald L. Tollinger as applications engineer. Thomas F. Corbet assumed engineering cognizance in March 1962.

The program was initiated 1 June 1960, under Contract DA 44-177-TC-641 and was organized to support the determinations set forth in Staff Study, Project 9R-38-01-017-55, House Task 12.129, dated February 1960. Project identification was amended effective November 1960 to Project 9R-89-02-015-16.

The extensive technical data necessary for aircraft analysis were provided through the cooperation of various government agencies, vendors, and manufacturers, with specific comparative and analytical data derived from ALARM project documentation.

Special acknowledgement is made of the technical information and cooperation provided Project ALARM by the staff and personnel of the U. S. Army Transportation Research Command, Fort Eustis, Virginia.

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SUMMARY

This report contains a detailed discussion of the application of an Automatic Light Aircraft Readiness Monitor system (ALARM) implementation to Army aircraft. Studies were made relative to the feasibility of applying the ALARM engineering philosophy to a specific group of Army aircraft. This group includes the following:

H-13

H-23

H-37

HC-1

L-19

AC-1

AO-1

The HU-1 aircraft application is covered by TRECOM Technical Report 63-10, Volumes I, II, and III.

Specific applications of the philosophies of ALARM implementation are detailed for each of the preceding aircraft, together with supporting graphic presentations and analytical data. For convenience, the technical discussions are presented in the following order:

ALARM System Applications, General

Table 1, H-13 Helicopter, ALARM Application

Table 2, H-23 Helicopter, ALARM Application

Table 3, HC-1 Helicopter, ALARM Application

Table 4, L-19 Fixed Wing, ALARM Application

Table 5, AC-1 Fixed Wing, ALARM Application

Table 6, AO-1 Fixed Wing, ALARM Application

Table 7, H-37 Helicopter, ALARM Application

Table 8, System Costs

CONCLUSIONS

Initial studies and investigations have determined that the ALARM System implementation in Army aircraft is feasible, realistic, and practical. These conclusions are supported by an estimate based on available information that the over-all ALARM daily inspection may result in considerable time savings. As applicable to the aircraft types discussed in this report, this means the daily inspection time savings should approximate hundreds of man-hours for a single cumulative inspection based upon the total number of each of these aircraft in the Army system.

In addition, thorough studies indicate that the average estimated flight safety and inspection improvements through ALARM implementation of these representative type aircraft will enhance safety of flight through an indication of the internal integrity of dynamic components.

The conclusions are predicated on the results of the extensive studies and comparisons of all available documents and information provided. Although certain information was inadequate, it provided a base for analysis and document research.

The Applications Report must be construed as essentially preliminary information since a firm decision to implement any or all of the aircraft will require detailed study to determine detection levels, exact sensor locations and the precise mounting assemblies required.

Although the scope of the applications study has been limited, it is obvious that utilization of the ALARM System enhances existing IROAN concept, particularly through vibration, temperature, pressure, and filter bypass monitoring. In addition, human judgement and decision are removed regarding visual, aural, or tactile methods which are presently used and are a function of skill level and experience.

Inasmuch as ALARM is considered a permanent installation, no special tools or operational skill levels will be required.

RECOMMENDATIONS

It is recommended that an ALARM System be installed in a minimum of two each of the aircraft referenced in this document to determine specific operating limits, particularly in the areas of vibration and temperature. These data cannot be obtained from present documentation and are essential to augment the operation, flight safety, and maintenance information to improve function in these areas.

It is also recommended that a comprehensive study program be immediately initiated to determine the location for vibration and temperature sensors to obtain the most reliable data.

In addition, it is recommended that a program be undertaken to implement aircraft with the ALARM System designed as an integral part of the aircraft during the aircraft design phase.

The recommendation is made to implement a program to investigate the feasibility of other techniques and methods of monitoring aircraft conditions for incorporation in the ALARM System. These would include, but not be limited to, the following:

1. Oil and fuel leak detection at all rpm
2. Engine over temperature (turbine hot-start)
3. Engine flame out (turbine)
4. Smoke and flame detection
5. Engine over torque (rotary wing)
6. Strain gage and load cell applications

An additional recommendation suggests that the present inspection procedure be revised and based upon the capabilities of the ALARM System. This recommendation is a step toward the IROAN concept of aircraft maintenance.

ALARM SYSTEM APPLICATIONS

GENERAL

It is the purpose of this document to report on the specific application of ALARM System implementation to Army aircraft. The recommended monitor points for the various aircraft resulted from basic and advanced studies of material contained in the bibliography which was pertinent to these representative aircraft. Recommendations are based on standard aircraft configurations, in that no special consideration is given to variations existing between aircraft due to different model or serial numbers.

The following representative aircraft were selected for inclusion in this report:

H-13
H-23
HC-1
L-19
AC-1
AO-1
H-37

In addition, the HU-1 aircraft has been implemented with a breadboard ALARM System and is undergoing field tests. The implementation of this aircraft is covered in detail in TRECOM Technical Report 63-10, Volumes I, II, and III.

The selection was made on the basis that these aircraft represented approximately 60% of the aircraft types employed by the Army. In addition, the studies were applied and directed to follow the trend of reducing the number of aircraft models to improve efficiency, economy, and utilization. Included as part of this consideration are:

Replacement of the H-19, H-34, H-21, together with L-20's with the HU-1 helicopter for general utility application.

H-37, H-34, and H-21, to be replaced by the HC-1 Chinook as the basic transport cargo helicopter.

AC-1 Caribou to replace the fixed wing U-1A as a transport aircraft.

AO-1 Mohawk to replace the RL-23 and RL-26 for combat surveillance.

It is also proposed to replace the existing L-23 and L-26 with the L-23 F which employs turbine engines. In addition, the L-23 F is envisioned for service as a utility transport aircraft.

Inasmuch as the proposed ALARM instrumentation for the AO-1 Mohawk is considered to be similar to the system which would be applied to the L-23 F, it was not deemed necessary to incorporate a report for this aircraft.

The H-13, H-23, and L-19 are included inasmuch as they are presently utilized by the Army in substantial numbers. In addition, phase-out of these aircraft is not anticipated until a later date when a turbine powered light observation helicopter is considered as a replacement. It is envisioned that the details and recommendations provided for the H-13 and H-23 aircraft will parallel similar installations for the new type aircraft.

It must also be noted for the purpose of this report that availability and adequacy of documentation pertinent to Army aircraft also influenced selection of the six aircraft reported in this document. The voluminous research points up the necessity of more detailed documentation pertinent to vibration and temperature areas on aircraft proposed for Army utilization.

This report has proposed the ALARM System as an integral part of the aircraft for two reasons. The first is that the capability of the system enables it to be a ground checkout as well as a flight-safety item. The flight-safety aspects were considered of sufficient scope to warrant the permanent installation in the aircraft.

The second reason is that the detection levels of each channel will undoubtedly vary with different types of aircraft. An example of this would be engine vibration. The vibration level on the L-19 would vary considerably from the level of the H-37. The ALARM System would become considerably more complex if the indicating levels were made to vary automatically with each type of aircraft. In addition, it is suspected that the levels of temperature and vibration would vary from aircraft to aircraft of the same type. Such a variation would require even more indicating level controls. This can be accomplished but would be considerably more complex and hence more expensive. An item of ground checkout equipment with these capabilities and designed to work in conjunction with the ALARM System has been proposed by Bendix York. The nomenclature designating this equipment is PACER (Portable Aircraft Condition Evaluator/Recorder). The proposal and design of a breadboard PACER System is controlled by USATRECOM Project 9R89-02-015-16, Contract DA 44-177-TC-750.

Selection of specific monitor points was based on the following criteria to fulfill ALARM objectives of inspection-time savings, improved flight safety, and inspection effectiveness:

1. Feasibility
2. Practicability
3. Results obtained from JHU-1 Test Bed

The scope and effect of the preceding items can be clarified by examining three general inspection requirements.

For example, there is presently no conceivable means available for "automatically" inspecting the windshield and airframe for cleanliness; nor is it considered feasible to automate inspection of fuselage or control surfaces for defects, due to the complex instrumentation required and the unpredictable nature of the appearance and location of such defects.

Inspection for security of flight compartment entrance doors is feasible, utilizing interlock switches. However, due to wiring requirements and ease of visual inspection, implementation is impractical. Further, ALARM test results indicated that monitoring of certain types of latching mechanisms was unreliable and of questionable value to aircraft flight capability.

In the discussions pertinent to each specific aircraft, ALARM monitoring has been cataloged into general categories (channels), according to the type of proposed implementation. These are:

1. Interlocks
2. Continuity
3. Liquid Level
4. Temperature
5. Filter Bypass
6. Vibration
7. Oil Flow
8. Other

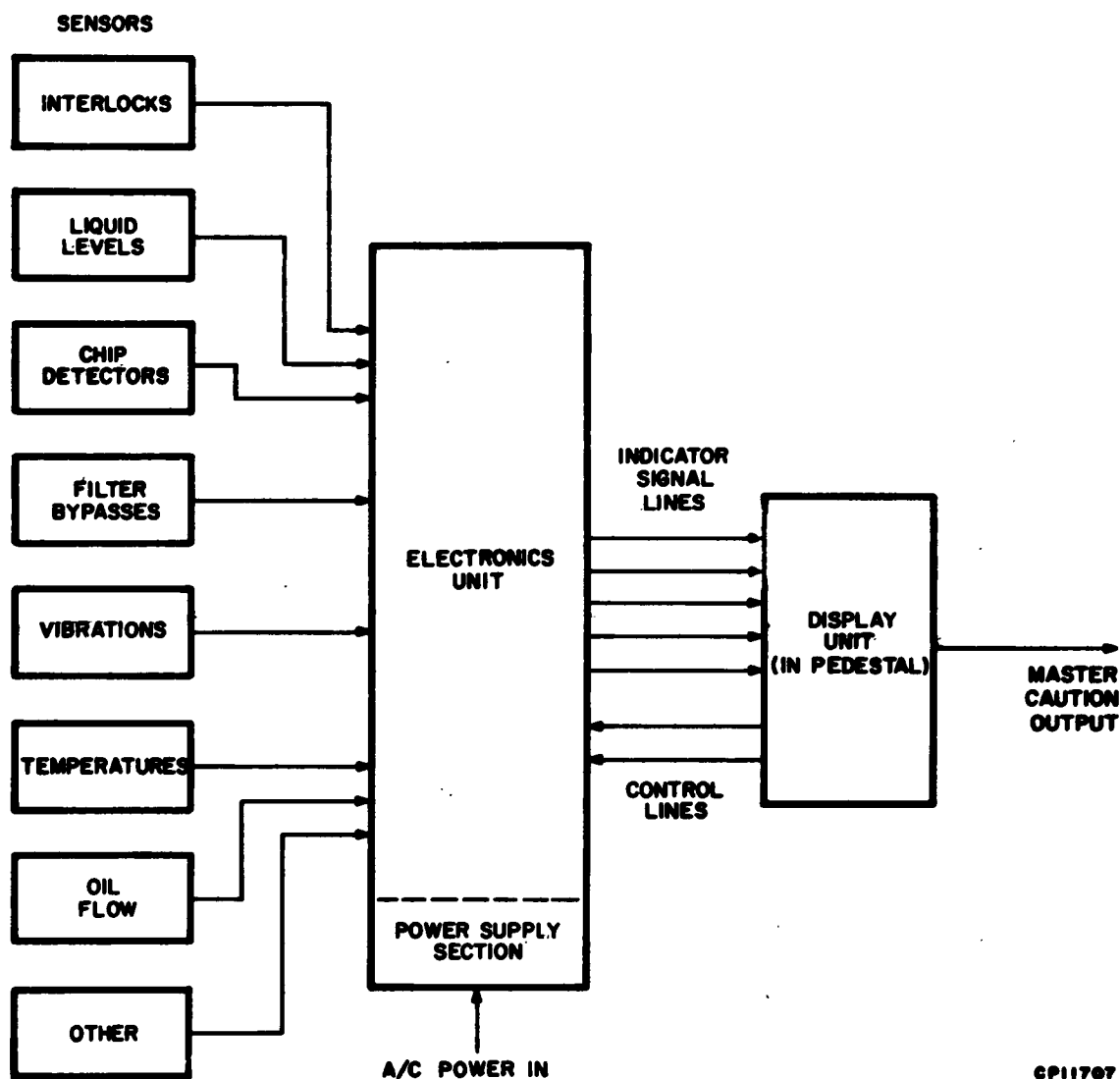
The first seven type channels have been used in the ALARM test bed (JHU-1), while the eighth channel is included to provide concepts which may not presently be monitored but may be applicable to other aircraft configurations.

Data obtained from these channels will be electronically evaluated and displayed on GO/NO GO indicators in the cockpit. Figure 1 is a block diagram of a typical system showing Sensors, Electronic Unit, and Display Unit. Sensor cable routing, as well as Electronic Unit location, will be determined by detail studies contingent upon the aircraft configuration to be implemented. It is important to note that the Electronic Unit can be located anywhere in the aircraft to maintain balance and utilize available space. One small cable connects to the Display Unit, located in the cockpit as desired.

The ALARM System, as proposed, has been designed to be permanently installed in the A/C, and the design and packaging is compatible with "General Specification for Aircraft Electronic Equipment" (MIL-E-5400).

Figure 2 shows the Electronic Unit, which will be designed as a standard airborne electronics package complete with shock-mount provisions. This unit contains signal processing circuitry, power modules, self-check circuitry, and control relays. All solid-state circuits are employed, mounted on printed circuit boards as shown. There are no controls on this unit with the singular exception of provisions for screwdriver adjustment of detection levels. A number of test jacks are provided to permit external recording equipment to be connected directly to the sensors for data recording purposes.

It will become apparent later in this report that the various aircraft will have different channel requirements creating a need for more display indicators and supporting circuitry on some aircraft than on others. For this reason specific case dimensions



GP11707

FIGURE 1. BLOCK DIAGRAM, TYPICAL ALARM SYSTEM

are not assigned to the sketch of Figure 2 as these will be tailored for the particular aircraft being implemented to optimize weight/volume requirements.

Figure 3 details the Display Unit designed primarily for mounting in the aircraft instrument pedestal. The case dimension "L" (length) will vary, depending upon the number of required channels while the width and depth will be as shown in order to be compatible with standard mounting facilities. The Mode Switch is so designed that the test position is spring loaded to prevent locking in this position. No ON-OFF control is provided since a voltage-sensing relay energizes the system when the operator actuates the aircraft power sources.

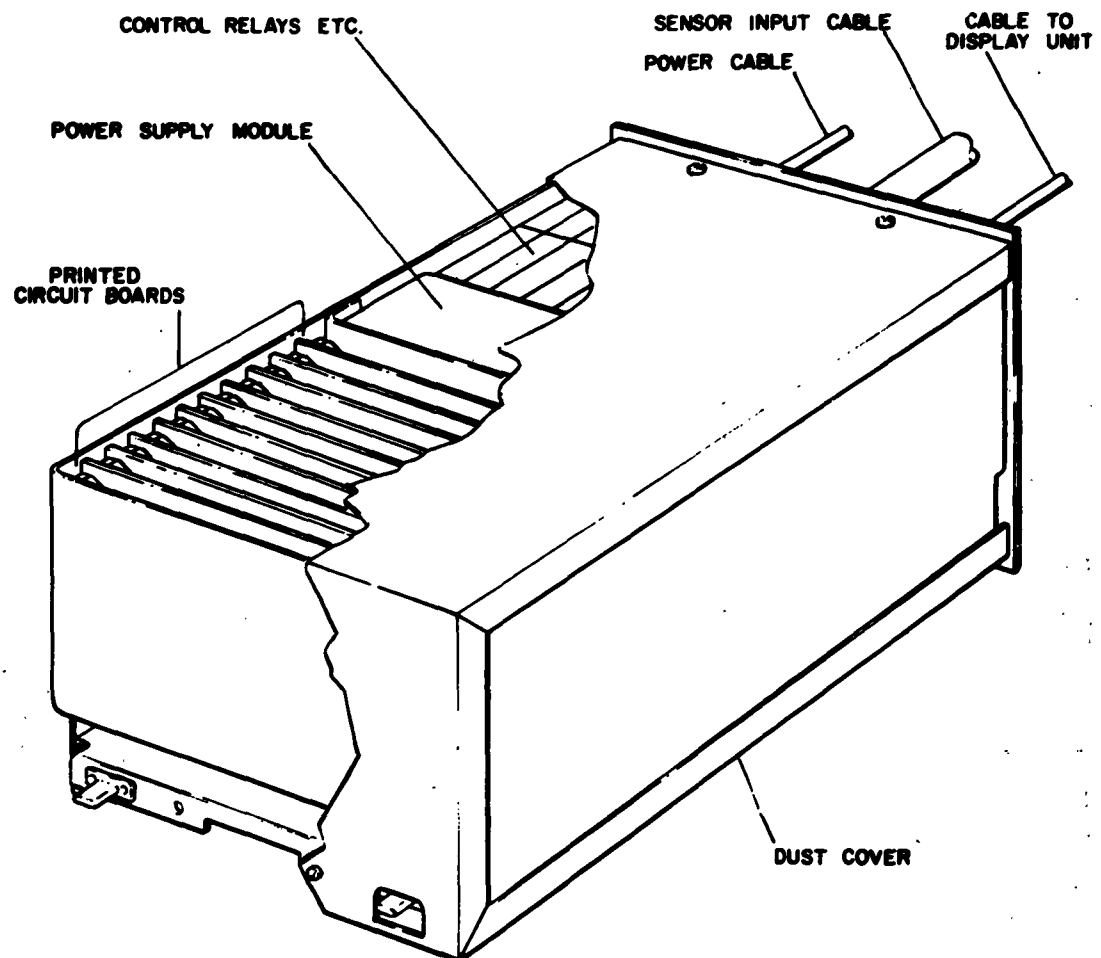


FIGURE 2. ELECTRONIC UNIT, ALARM SYSTEM

With regard to proposed sensor locations, time savings, and improved effectiveness, effort expended during this study concentrated primarily on automation of prescribed pre-flight, post-flight, and daily inspection procedures. Present procedures were investigated, combined where possible, and automated when feasible. In addition, certain procedures presently associated with periodic inspections are implemented by ALARM and, therefore, are included.

A major point to be noted is that this

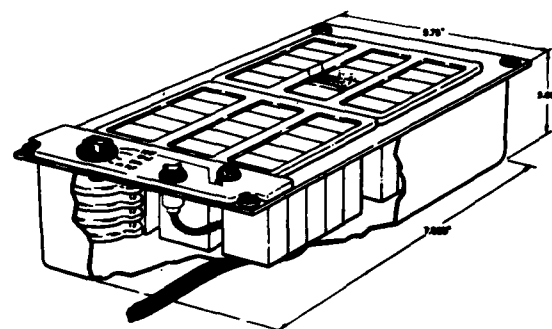


FIGURE 3. ALARM DISPLAY UNIT

particular investigation dealt with the presently documented procedures most vigorously, whether these procedures are recognized as adequate, or essential to flight safety.

Application of ALARM is presented on seven aircraft in the following sections. These consist of the H-13, H-23, H-37, HC-1, L-19, AO-1, and AC-1. A brief discussion and sketch of each aircraft is provided, together with the approximate location of proposed monitoring points or general areas identified by numbers. Also, included with each aircraft section are bar-graph presentations of time savings and improved inspection effectiveness resulting from ALARM utilization.

Average daily inspection times were used as a basis for comparison since reliable data on pre- and post-flight times are not available at our facilities. It is important to note, however, that daily inspections include items checked at every pre- and post-flight and, therefore, reflect time savings to these inspections.

While not included in the time saving comparisons, ALARM will place the equivalent of 16 to 108 man-minutes (depending on the aircraft) of periodic inspection time required to inspect magnetic plugs and filter assemblies, at the pilot's or maintenance personnel's disposal instantaneously. An estimate of this time appears with each aircraft time savings.

Following each time comparison are aircraft system block diagrams with the estimated percent improved effectiveness to inspections and flight safety of these systems.

No attempt is made to compare present effectiveness with ALARM improvements, as was done with time savings, as there is no factual data on which to base a comparison. Present checkout procedures are functions of personnel training, experience, judgement, and environment of the using activity.

In addition to being exempt from these variables, ALARM utilizes temperature, vibration, and pressure techniques to discover abnormal conditions presently extremely difficult for the man of average skill level to detect by the senses of sight, hearing, and touch. Further, features are included to prevent oversights or omissions which may occur with present procedures.

Realizing the degree to which inspection is advanced through the application of the recommended channels, the major components and bar graphs reflect the estimated over-all improvements to pre-flight through periodic inspections and flight safety that would be acquired by adoption of ALARM.

It must be emphasized again that the statistics appearing in the discussions and graphical presentations are considered as conservative estimates. In addition, ALARM System operation will not require skilled personnel to perform the checkouts, nor special tools. These advantages are not reflected in the improved inspection effectiveness shown in graph form, but are extremely important in view of the increasing complexity of aircraft systems and the desire to incorporate IROAN concepts in aircraft maintenance programs.

TABLE 1. H-13 HELICOPTER, ALARM APPLICATION

(Figure 4. Sensor Points, H-13)

I. Interlock Channels

A. Fuel Caps - Secured	Pt. 1
B. Oil Cap - Secured	Pt. 2
C. Hydraulic Cap - Secured	Pt. 3
D. External Power - Disconnected	Pt. 4

The above, with the exception of item D, are a part of every pre-flight and daily inspection, and ALARM monitoring will eliminate time required to visually inspect as well as improve effectiveness by preventing omissions. Item D is recommended to prevent the pilot from attempting taking off with an auxiliary power supply connected to the aircraft.

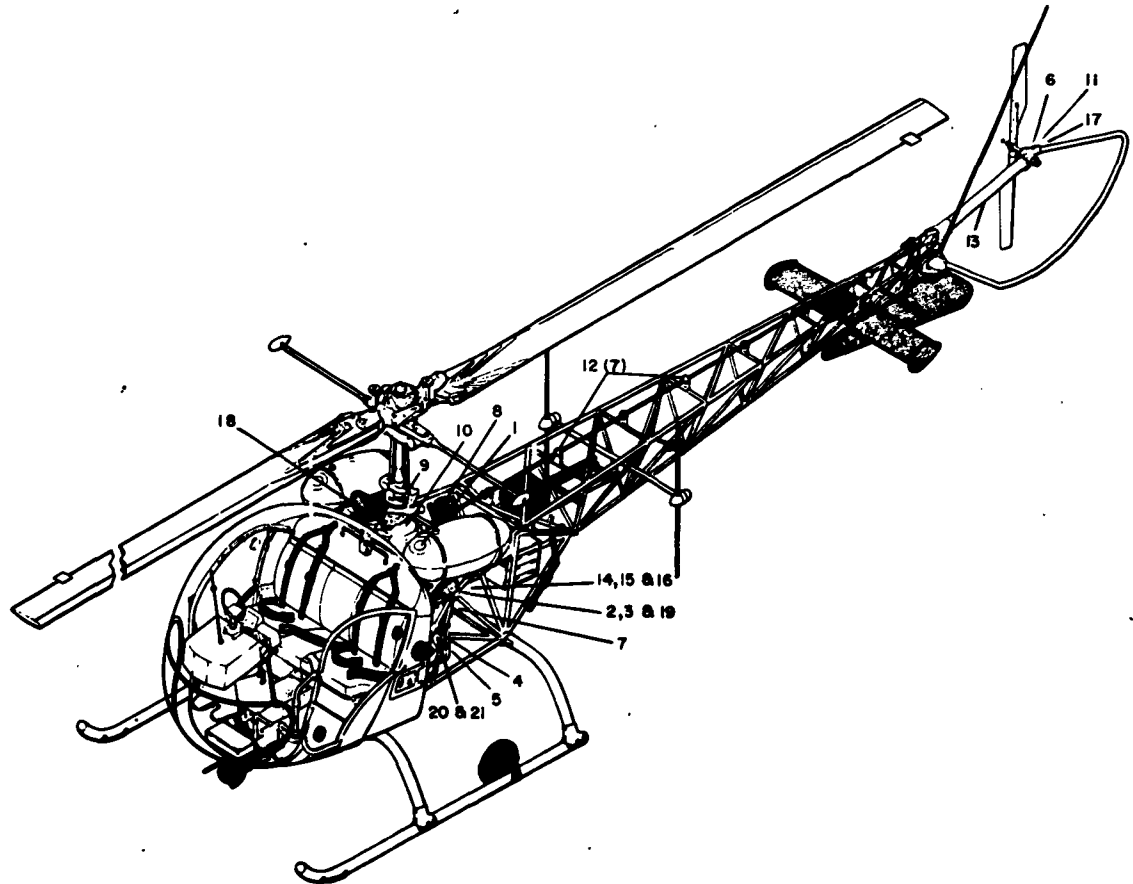


FIGURE 4. H-13 SENSOR POINTS

II. Continuity Channels

- | | |
|---|--------------|
| A. Engine Oil Sump Chip Detector | Pt. 5 |
| B. Tail Rotor Gear Box Chip Detector | Pt. 6 |

Items A and B are proposed to place on an instantaneous basis the approximate 10-20 minutes of periodic inspection time required to remove the engine magnetic sump plugs and to strain the oil from the tail gear to examine for ferrous material. ALARM monitoring will, therefore, provide increased flight safety and inspection effectiveness by providing the equivalent of the periodic requirement to the pre-flight, post-flight and daily inspection levels.

III. Liquid Level Channels

- | | |
|--------------------------------|--------------|
| A. Engine Oil Tank | Pt. 7 |
| B. Hydraulic Fluid Tank | Pt. 8 |

Inspection of these levels is required at every pre-flight and daily inspection to determine if servicing has been accomplished. Implementation would replace visual requirements with resultant time savings and an increased confidence factor.

IV. Temperature Channels

- | | |
|--|---------------|
| A. Swashplate Bearing | Pt. 9 |
| B. Transmission Mast Bearing | Pt. 10 |
| C. Tail Gear Box -90° | Pt. 11 |
| D. Drive Shaft Hanger Bearings (7) | Pt. 12 |
| E. Tail Boom Extension Bearings (2) | Pt. 13 |
| F. Engine Oil Outlet | Pt. 14 |
| G. Magneto Temperature | Pt. 15 |

The above items are not presently instrumented on the aircraft and their implementation will provide increased inspection effectiveness by GO/NO GO condition presentation of safety of flight components.

V. Filter Bypass Channel

- | | |
|-----------------------------|---------------|
| A. Engine Oil Filter | Pt. 16 |
|-----------------------------|---------------|

Monitoring for impending bypass or flow stoppage would provide continuous indication of the condition of filtering elements, as opposed to the present time-consuming method of removal and disassembly at periodic inspections.

VI. Vibration Channels

- | | |
|---|---------------|
| A. Tail Rotor Assembly - Velocity Transducer | Pt. 17 |
| B. Transmission - Accelerometer Transducer | Pt. 18 |
| C. Engine - Velocity Transducer | Pt. 19 |

The three recommended areas presently required extensive visual inspection as well as judgement of sound levels and feel to determine their status. ALARM monitoring will improve present inspections by monitoring the vibrations originating from bearings, gears, and associated rotating components, thereby eliminating human judgement and possible oversight.

VII. Oil Flow Channel

- | | |
|-----------------------------------|---------------|
| A. Engine/Transmission Oil | Pt. 20 |
|-----------------------------------|---------------|

Implementation of the engine inlet and/or outlet oil flow would be used to detect leaks in the system or excessive oil consumption. Further study is required to determine the variation in flow rate with power settings of the engine before limits could be established.

VIII. Additional Recommended Channel

- | | |
|------------------------------|---------------|
| A. Hydraulic Pressure | Pt. 21 |
|------------------------------|---------------|

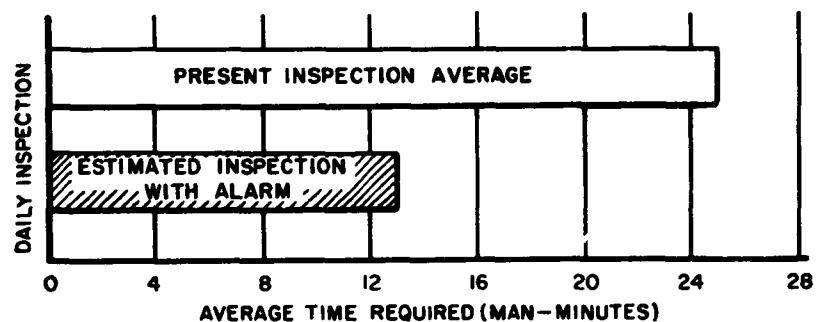
The present aircraft hydraulic system is not monitored. The ALARM System could provide an indication of high and/or low system pressure by installation of transducers with resultant improved flight safety.

Figure 5 is a graphic comparison of the average daily inspection time with and without ALARM implementation.

An average of 25.2 man-minutes is presently required to inspect the aircraft while with ALARM implementation it is conservatively estimated that this time will be reduced by 48% to 13.1 man-minutes as shown. This 13.1 man-minutes will remain to check items impractical for ALARM monitoring.

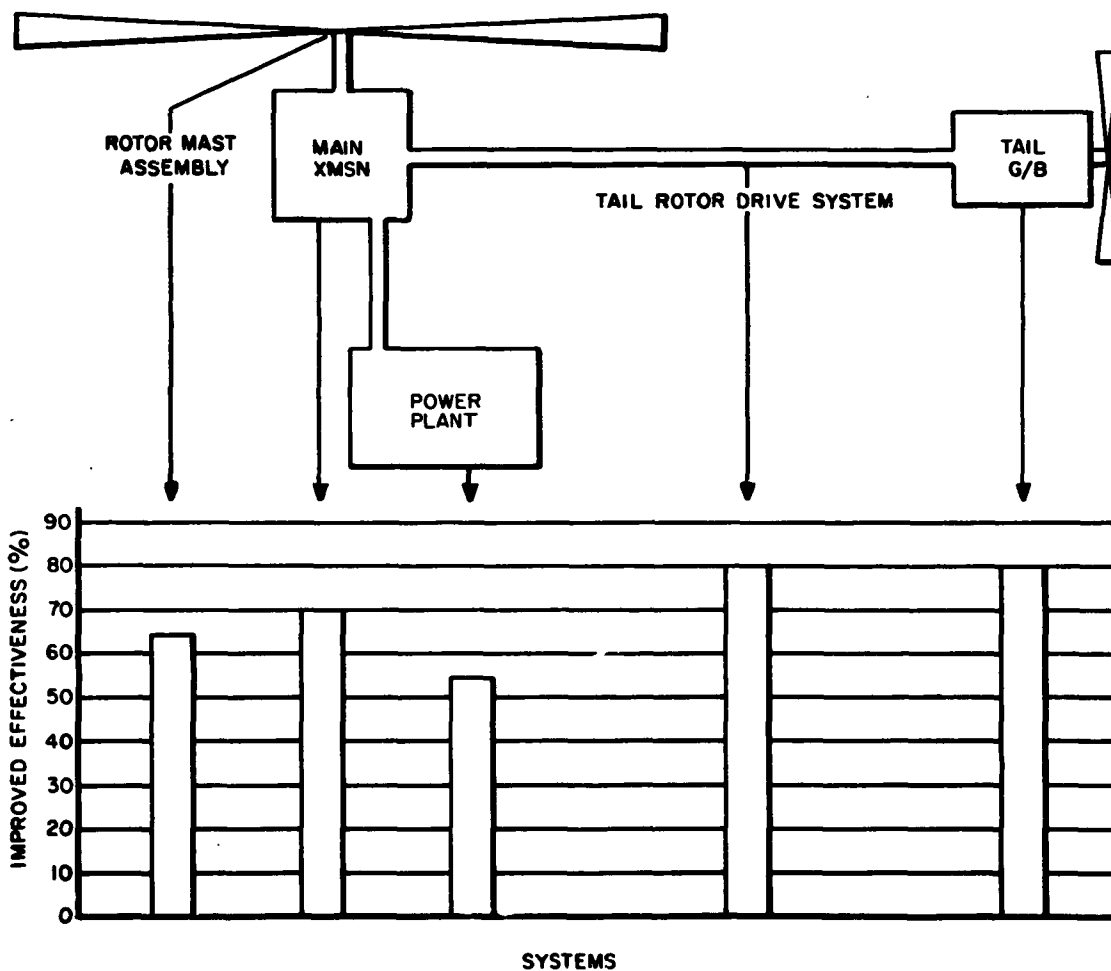
The illustration does not include the approximate 23 man-minutes of periodic inspection time which ALARM will place at the disposal of personnel during pre-flight, post-flight, and daily inspection on an instantaneous basis through chip detection and filter bypass monitoring.

Figure 6 illustrates the major aircraft systems with associated bar graphs showing the estimated percentage of improved effectiveness in inspections and flight safety by utilization of the ALARM channels presented in Table 1.



CP10988

FIGURE 5. H-13 ESTIMATED ALARM INSPECTION TIME SAVINGS



CP10988

FIGURE 6. H-13 ESTIMATED IMPROVED INSPECTION EFFECTIVENESS WITH ALARM

TABLE 2. H-23 HELICOPTER, ALARM APPLICATION

(Figure 7. H-23 Sensor Points)

I. Interlock Channels

A. Fuel Cap - Secured	Pt. 1
B. Oil Cap - Secured	Pt. 2
C. External Power - Disconnected	Pt. 3

Implementation of the filler caps would eliminate visual inspection requirements while Item C is suggested as a flight safety provision prior to take-off.

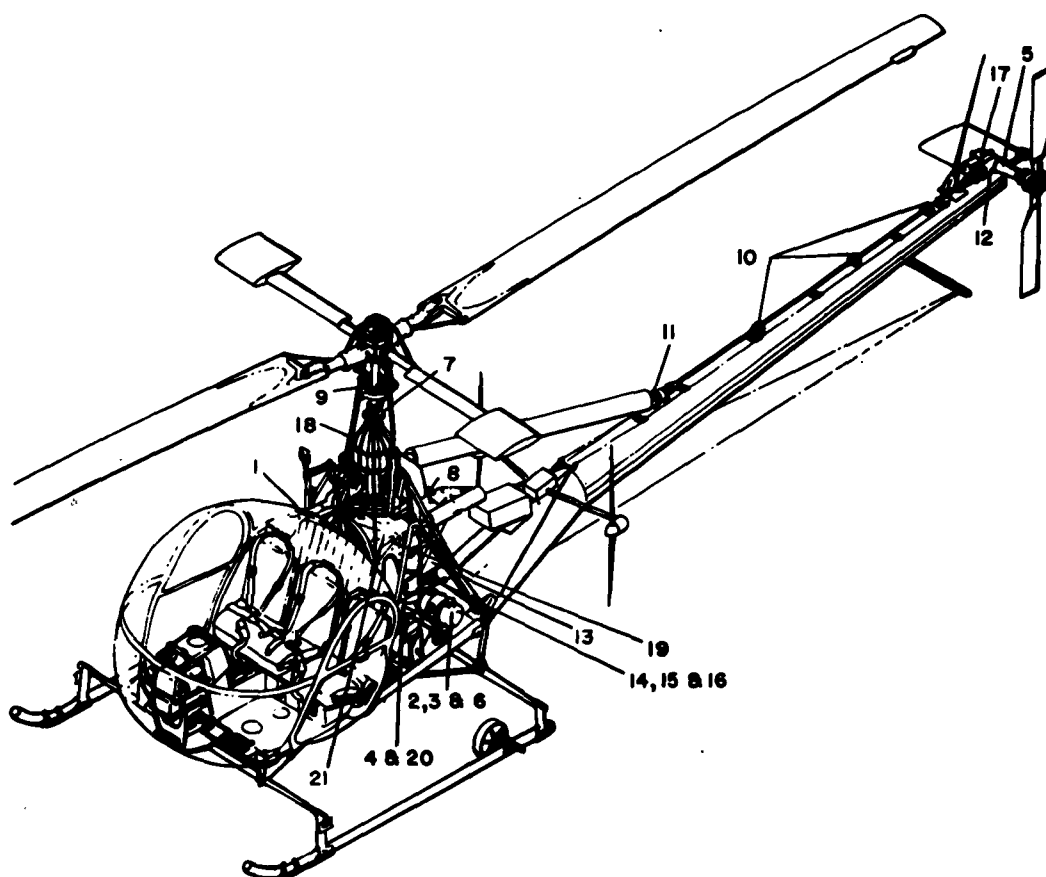


FIGURE 7. H-23 SENSOR POINTS

II. Continuity Channels

- | | |
|--------------------------------------|-------|
| A. Engine Oil Sump Chip Detector | Pt. 4 |
| B. Tail Rotor Gear Box Chip Detector | Pt. 5 |

Replacement of the existing magnetic plug in the engine sump with a chip detector will eliminate the need to remove and visually inspect for ferrous metal accumulation. The addition to the gear box would remove the requirement of draining and straining the oil to discover metallic particles.

III. Liquid Level Channel

- | | |
|--------------------|-------|
| A. Engine Oil Tank | Pt. 6 |
|--------------------|-------|

Pre-flight and daily inspections of this level would be placed on an automatic basis by this installation.

IV. Temperature Channels

- | | <u>Approximate
Indicating Level</u> | |
|-----------------------------------|---|--------|
| A. Transmission Main Mast Bearing | | Pt. 7 |
| B. Clutch | (45°C) | Pt. 8 |
| C. Wobble Plate Bearing | (20°C) | Pt. 9 |
| D. Shaft Hanger Bearings - (3) | (15°C) | Pt. 10 |
| E. Cardan Joint | (10°C) | Pt. 11 |
| F. Tail Gear Box | (10°C) | Pt. 12 |
| G. Engine Oil Return | (140°C) | Pt. 13 |

ALARM monitoring of the preceding items is recommended to improve inspection effectiveness and flight safety by detecting abnormal temperatures resulting from improper lubrication or deterioration.

Detection levels will be automatically adjusted by ambient temperature changes, and approximate normal operating surface temperatures above ambient are shown in parenthesis.

V. Filter Bypass Channels

- | | |
|---------------------|--------|
| A. Fuel | Pt. 14 |
| B. Transmission Oil | Pt. 15 |
| C. Engine Oil | Pt. 16 |

Instrumentation is recommended to monitor continuously for impending filter stoppage (or bypass) and thus provide automatic inspection of a condition presently determined only by filter removal and disassembly during periodic inspections

VI. Vibration Channels

- | | |
|------------------------------------|--------|
| A. Tail Gear Box - Velocity Pickup | Pt. 17 |
| B. Transmission - Accelerometer | Pt. 18 |
| C. Engine - Velocity Pickup | Pt. 19 |

Velocity pickups are recommended to detect changes in low frequency intensities as a result of latent defects in the power and drive systems which are difficult to detect by present inspection methods. Fundamental frequencies, at an engine rpm of 3100 rpm, would be approximately 6, 12, 34, 53, 4, 68, and 73.4 cps. The accelerometer on the transmission is applied to monitor the higher frequency vibrations associated with gear teeth and bearing noises.

VII. Oil Flow Channel

- | | |
|----------------------------|--------|
| A. Engine/Transmission Oil | Pt. 20 |
|----------------------------|--------|

Improved flight safety and inspection effectiveness would be obtained by providing ALARM indication in the event of an oil leak or excessive engine oil consumption.

VIII. Pressure Channel

- | | |
|--|--------|
| A. Fuel Carburetor Inlet - Low Pressure Switch | Pt. 21 |
|--|--------|

ALARM monitoring is recommended as a safety-of-flight feature, since the present pressure gage deflection appears to be quite small, making it difficult to detect a small change. The ALARM System would alert the pilot to a low pressure condition which may otherwise remain undetected until engine fuel starvation.

The average daily inspection times shown in Figure 8 are a comparison of the present procedures with that expected using the recommended ALARM channels of Table 2.

Present daily inspection requires an average of 22 man-minutes to perform. ALARM will reduce this time by approximately 52% to 10.5 man-minutes, as shown. This does not include the equivalent of 27 man-minutes of periodic inspection time provided by ALARM through chip detection and filter bypass monitoring.

Figure 9 is a block presentation of the major aircraft components and the expected percent improved effectiveness of inspection and flight safety to these items which will be realized using the ALARM System.

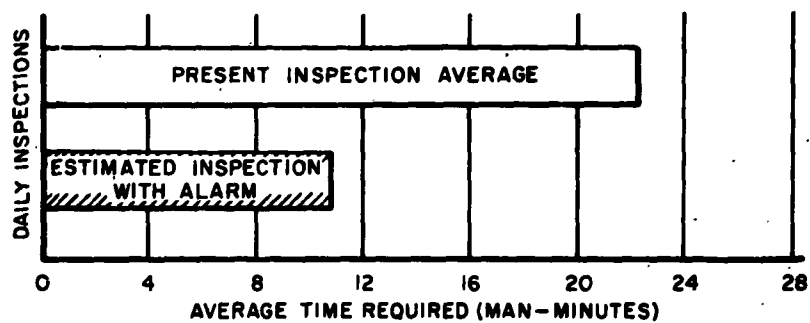


FIGURE 8. H-23 ESTIMATED ALARM INSPECTION TIME SAVINGS

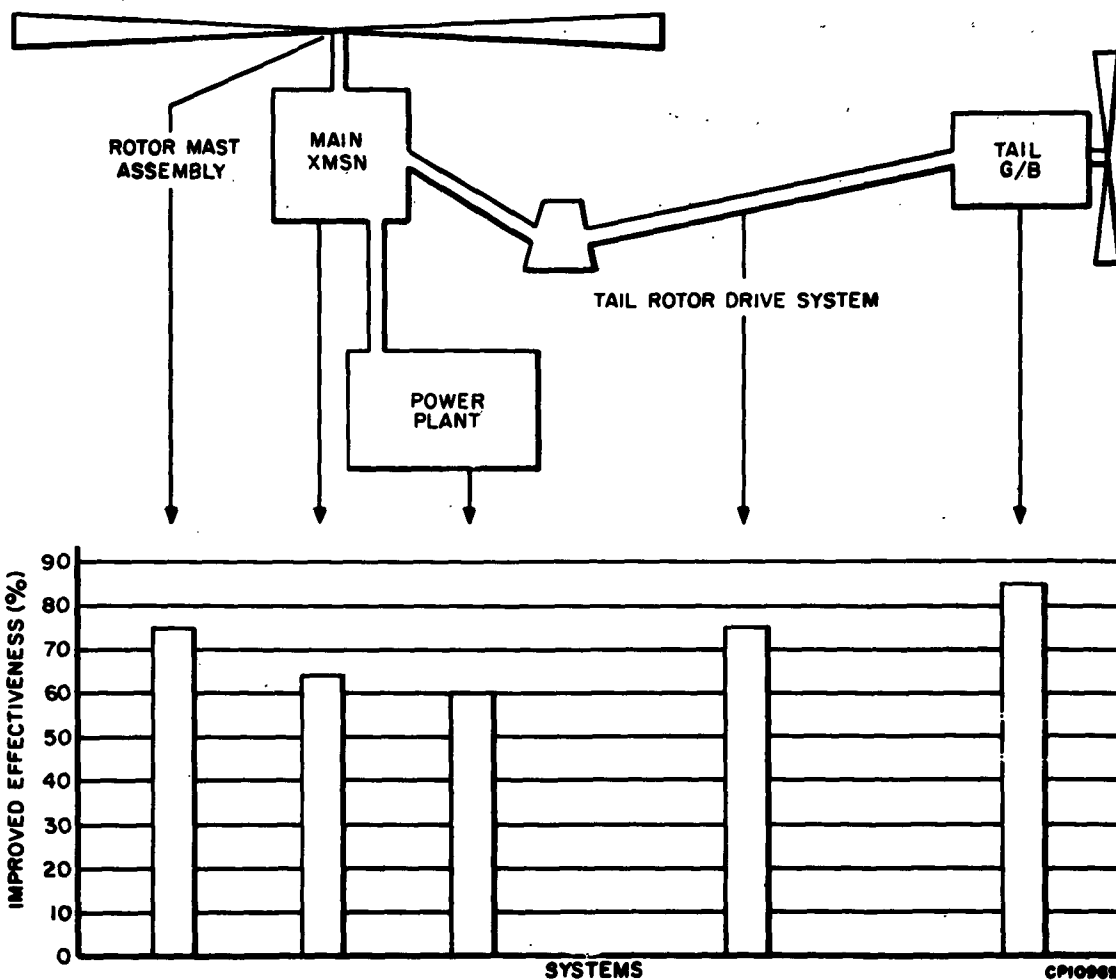


FIGURE 9. H-23 ESTIMATED IMPROVED INSPECTION EFFECTIVENESS WITH ALARM

TABLE 3. HC-1 CHINOOK, HELICOPTER, ALARM APPLICATION

(Figure 10. HC-1 Chinook Sensor Points)

I. Interlock Channels

A. Entrance Doors - Locked	Pt. 1
B. Emergency Exits - Secured	Pt. 2
C. Transmission Work Platforms and Cowlings - Secured	Pt. 3
D. Engine Cowlings and Access Doors - Secured	Pt. 4
E. Electrical Access Doors - Secured	Pt. 5
F. Fuel Caps - Secured	Pt. 6
G. Oil Caps - Secured	Pt. 7
H. Hydraulic Caps - Secured	Pt. 8

A security check of the above items is required on pre-flight and daily inspections. ALARM implementation is suggested to reduce inspection time through automatic monitoring.

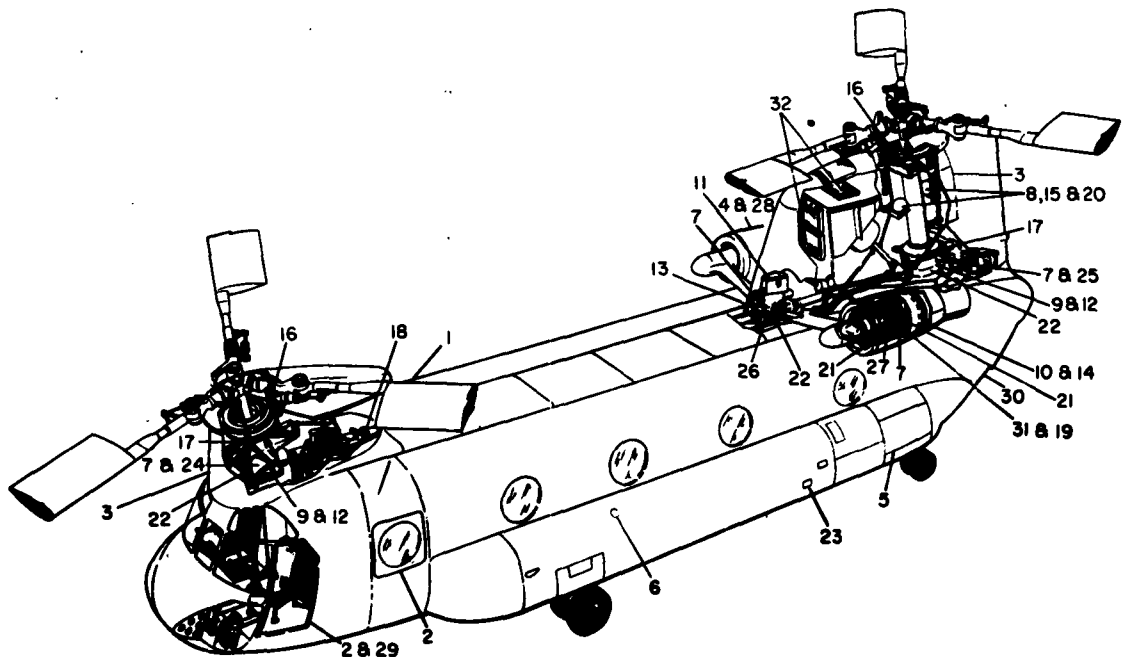


FIGURE 10. HC-1 CHINOOK SENSOR POINTS

II. Continuity Channels

- | | |
|--|--------|
| A. Forward and Aft Transmission - Chip Detectors | Pt. 9 |
| B. Engine Oil Sumps - Chip Detectors | Pt. 10 |
| C. Mixing Gear Box Chip Detector | Pt. 11 |

Replacement of existing magnetic plugs with electric chip detectors is recommended to eliminate the necessity for removal to examine for ferrous build-up during daily inspections.

III. Liquid Level Channels

- | | |
|-------------------------------------|--------|
| A. Forward and Aft Transmission Oil | Pt. 12 |
| B. Mixing Gear Box Oil | Pt. 13 |
| C. #1 and #2 Engine Oil | Pt. 14 |
| D. Hydraulic | Pt. 15 |

ALARM monitoring will permit these inspections to be performed automatically from the cockpit, with resultant time savings at all inspection levels.

IV. Temperature Channels

- | | |
|--|--------|
| A. Transmission Swashplate Bearing (2) | Pt. 16 |
| B. Transmission Main Mast Bearing (2) | Pt. 17 |
| C. Shaft Hanger Bearings (6) | Pt. 18 |
| D. Engine Scavenge Oil (2) | Pt. 19 |

Instrumentation of the foregoing is recommended to improve flight safety by providing continuous inspection of the component condition as reflected by operating temperature. Abnormal temperatures in these areas can occur, due to inadequate lubrication or component deterioration.

V. Filter Bypass Channels

- | | |
|---------------------------|--------|
| A. Main Hydraulic Filters | Pt. 20 |
| B. Engine Oil Filters | Pt. 21 |
| C. Transmission Filters | Pt. 22 |
| D. Fuel Filter | Pt. 23 |

Presently, the hydraulic filters incorporate warning flags to indicate impending bypass. The ALARM implementation will provide central monitoring of the hydraulic filter conditions, as well as the engine fuel and transmission filters, thereby, improving flight safety and eliminating the need for visual inspection.

VI. Vibration Channels

A. Forward Transmission - Two high frequency pickups	Pt. 24
B. Aft Transmission - Two high frequency pickups	Pt. 25
C. Mixing Gear Box - One high frequency pickup	Pt. 26
D. Left Engine - Two medium frequency pickups	Pt. 27
E. Right Engine - Two medium frequency pickups	Pt. 28
F. Forward Fuselage - Low frequency pickup	Pt. 29
G. Aft Fuselage - Low frequency pickup	Pt. 30

Vibration monitoring by ALARM is proposed to discover latent defects undetectable by present inspection procedures and which can result in catastrophic failures.

Anticipated vibration characteristics are as follows:

Maximum allowable engine vibration

20 cps - 0.25 g (0.74 in./sec)

50 cps - 0.8 g (0.95 in./sec)

100 cps - 2.0 g (1.4 in./sec)

250 cps - 8.0 g (2.0 in./sec)

500 cps - 12.5 g (1.5 in./sec)

(Preceding values measured at mount pads)

Rotor Transmission Gear Boxes

390 cps - Amplitudes 15 g Vertical and 20 g Lateral and Longitudinal Gear Tooth Contact Frequencies

A. Transmissions

Sun and Planets - 405 cps

Spiral Bevel - 1090 cps

B. Compressor - 440 cps

C. Power Turbine - 325 cps

D. Blower Spiral Bevel - 3160 cps

E. Mixing Gear Box

Spur #1 - 3240 cps

Spur #2 - 9100 cps

VII. Oil Flow Channels

A. #1 and #2 Engine Oil Systems

Pt. 31

B. Fore and Aft Transmission Oil Systems

Pt. 32

Application of oil flow monitoring is recommended for detection of leaks and excessive oil consumption. Insufficient information precludes any definite limit specifications at this time.

Figure 11 is a graphic comparison of the HC-1 Average Daily Inspection times with and without the recommended ALARM System.

While this helicopter is not yet operational, the HC-1B(-20) Interim Manual states that the daily inspection can be performed by a mechanic of average skill level in 5.6 man-hours (336.0 man-minutes). Recommended ALARM monitoring will reduce this time by 88 man-minutes to 248 man-minutes or 4.1 man-hours, as shown. Note that the above time savings do not include an equivalent of 65 man-minutes of periodic inspection time, which ALARM will supplement by automatic monitoring for filter bypass conditions. Presently, the filters must be removed and disassembled to examine the elements for contaminants which could create bypass conditions. By ALARM implementation, this will be available to flight personnel instantaneously, with resulting improved flight safety and inspection effectiveness.

Figure 12 illustrates the HC-1 ALARM estimated inspection effectiveness improvement.

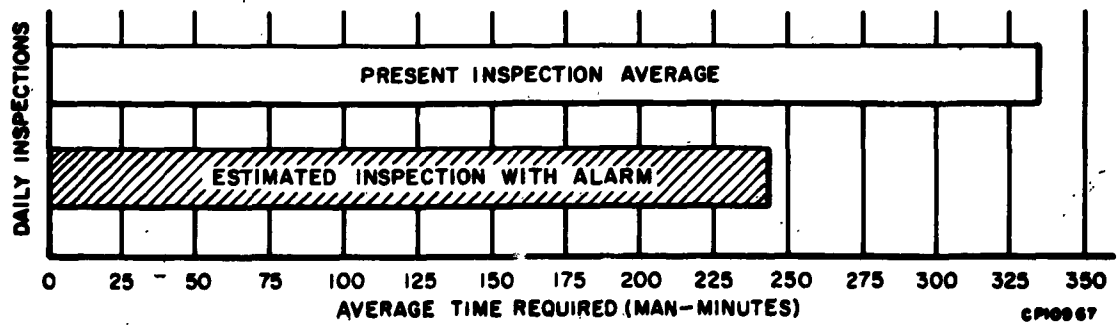


FIGURE 11. HC-1 ESTIMATED ALARM INSPECTION TIME SAVINGS

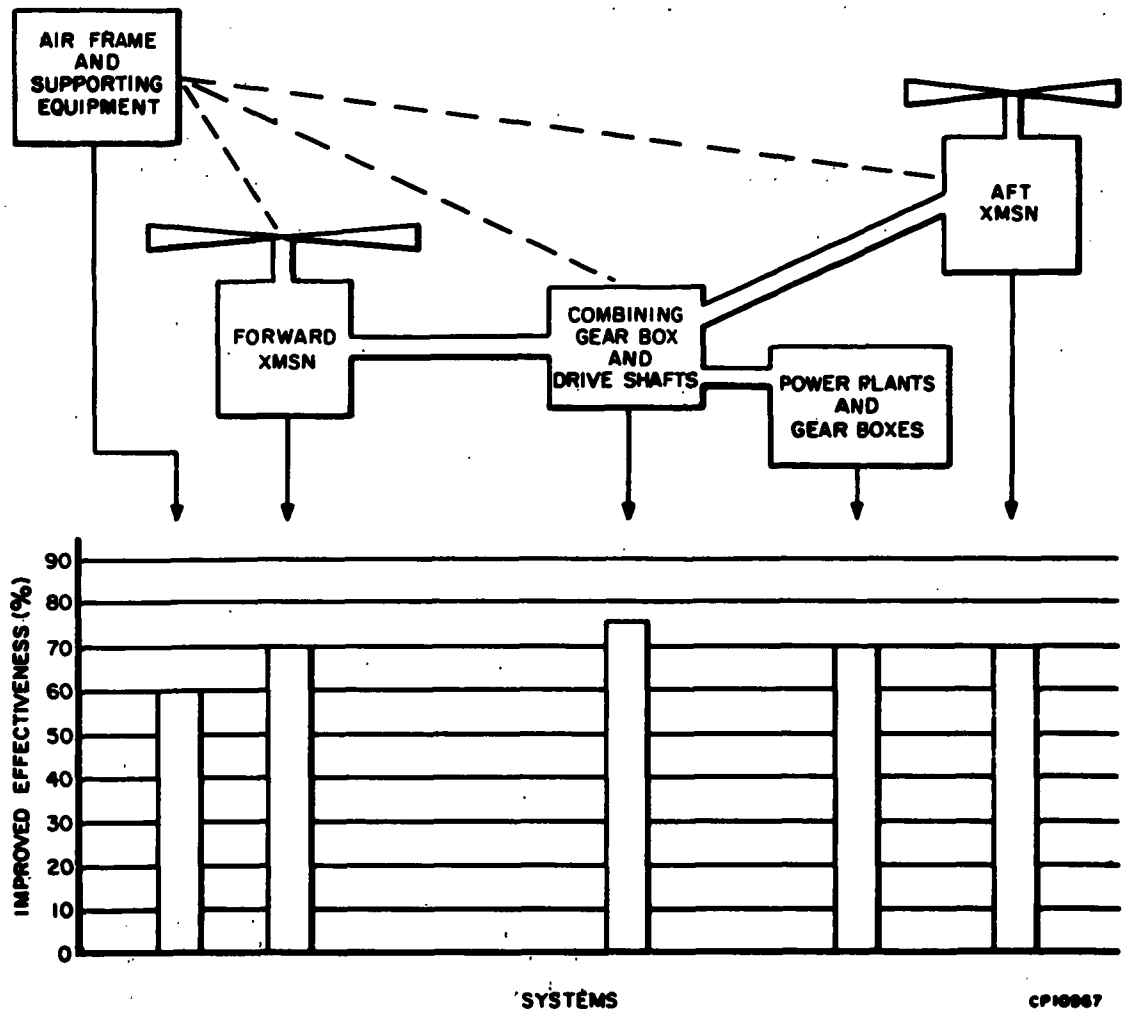


FIGURE 12. HC-1 ESTIMATED IMPROVED INSPECTION EFFECTIVENESS WITH ALARM

TABLE 4. L-19. FIXED WING. ALARM APPLICATION

(Figure 13. L-19 Sensor Points)

I. Interlock Channels

- | | |
|-------------------------------------|--------------|
| A. Fuel Caps - Secured | Pt. 1 |
| B. Oil Cap - Secured | Pt. 2 |
| C. Engine Cowlings - Secured | Pt. 3 |

Inspection of these items is required at every pre-flight and daily checkout, and ALARM implementation would place these requirements on an automatic basis.

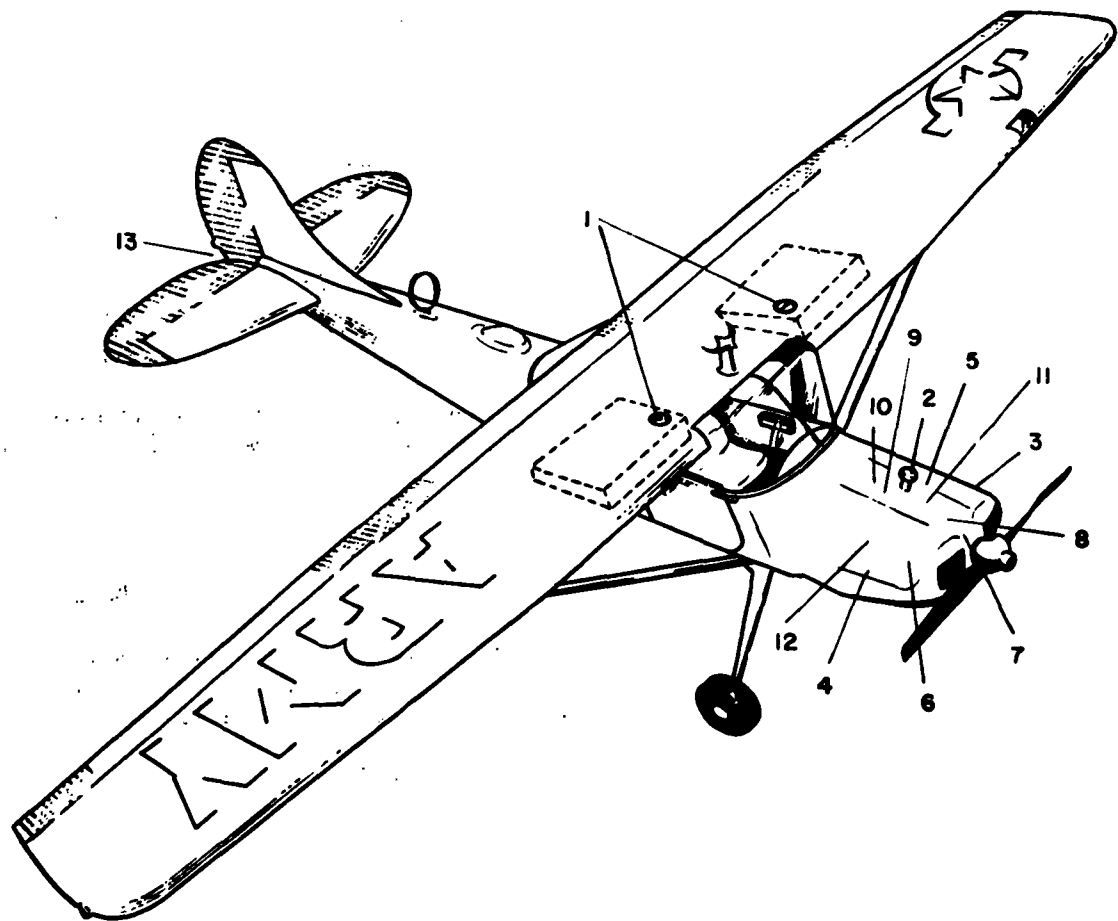


FIGURE 13. L-19 SENSOR POINTS

II. Continuity Channel

A. Engine Oil Sump Chip Detector

Pt. 4

Implementation with the ALARM System would place inspection of the oil sump for ferrous material accumulation on an instantaneous basis.

III. Liquid Level Channel

A. Engine Oil

Pt. 5

ALARM instrumentation is recommended to replace present visual inspection requirements.

IV. Temperature Channels

A. Engine Oil Outlet

Pt. 6

B. Propeller Governor Pump

Pt. 7

C. Magneto

Pt. 8

These channels are recommended for detection of latent defects not evident by visual inspection or present instrumentation.

V. Filter Bypass Channels

A. Engine Oil Filter

Pt. 9

B. Fuel Filter

Pt. 10

Implementation would improve flight safety and inspection procedures by monitoring for impending filter clogging or bypass. Presently, the filters must be removed and disassembled to inspect filter condition.

VI. Vibration Channel

A. Engine-Velocity Pickup

Pt. 11

Incorporation of an engine vibration pickup would improve present inspection procedures by examining the frequency spectrum generated by bearings, gears, valves, and crankshaft within the engine. Expected engine vibration characteristics:

**Fundamental - 26.6 to 43.3 cps, Harmonics to the 11th order,
Amplitude - less than 4 g's.**

VII. Oil Flow Channel

A. Engine Oil

Pt. 12

ALARM monitoring, with the limit referenced to power settings, would provide leak and/or excessive oil consumption detection with resulting increased inspection effectiveness.

VIII. Additional Channel

A. Elevator and Rudder-Full Travel

Pt. 13

Implementation is recommended to provide indication in the cockpit, prior to take-off, that tail control surface movements are not restrained by gust locks or improper rigging.

Figure 14 shows the L-19 estimated ALARM time savings graphically. The present average daily inspection time is 32.4 man-minutes.

The ALARM estimated time of 9 man-minutes is a 28% reduction in inspection time. Chip detector and filter bypass monitoring by the ALARM System will eliminate 16.5 man-minutes required for disassembly at periodic inspection.

Figure 15 illustrates the L-19 ALARM estimated improved effectiveness.

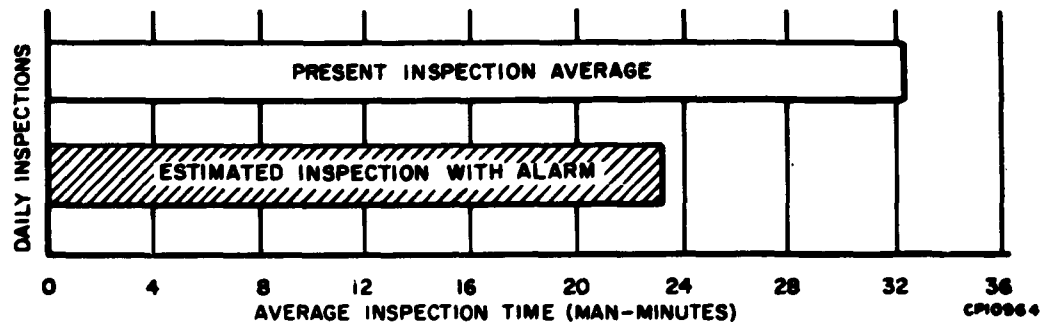


FIGURE 14. L-19 ESTIMATED ALARM INSPECTION TIME-SAVINGS

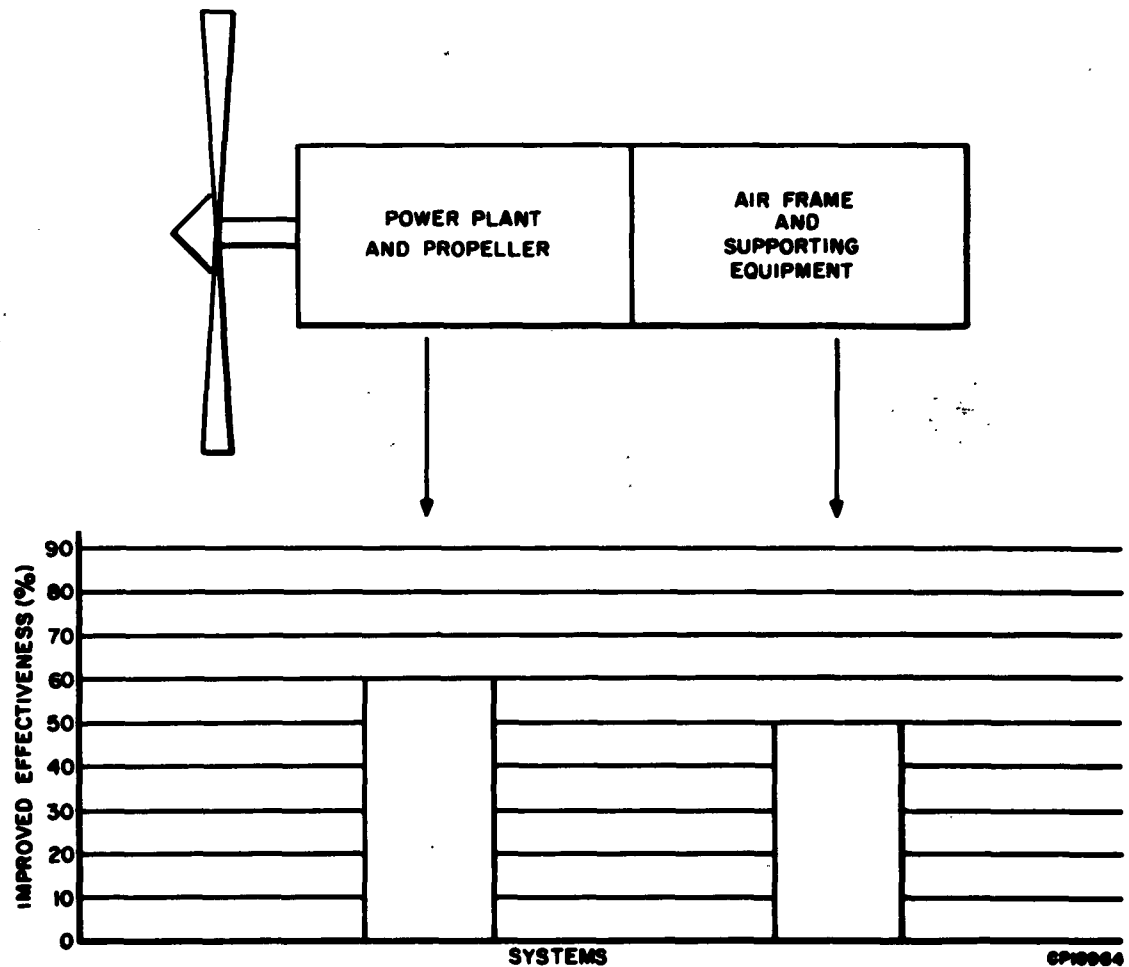


FIGURE 15. L-19 ESTIMATED IMPROVED INSPECTION EFFECTIVENESS WITH ALARM

TABLE 5. AC-1 CARIBOU, FIXED WING, ALARM APPLICATION

(Figure 16. AC-1 Caribou Sensor Points)

I. Interlock Channels

A. Two Main Landing Gear - Ground Safety Locks - Removed	Pt. 1
B. Nose Landing Gear - Ground Safety Locks - Removed	Pt. 2
C. Two Engine Cowlings - Secured	Pt. 3
D. Two Engine Oil Tank Caps - Secured	Pt. 4
E. Cabin Emergency Door - Secured	Pt. 5
F. Ramp Door Extensions - Stowed	Pt. 6
G. Hydraulic Reservoir Cap - Secured	Pt. 7

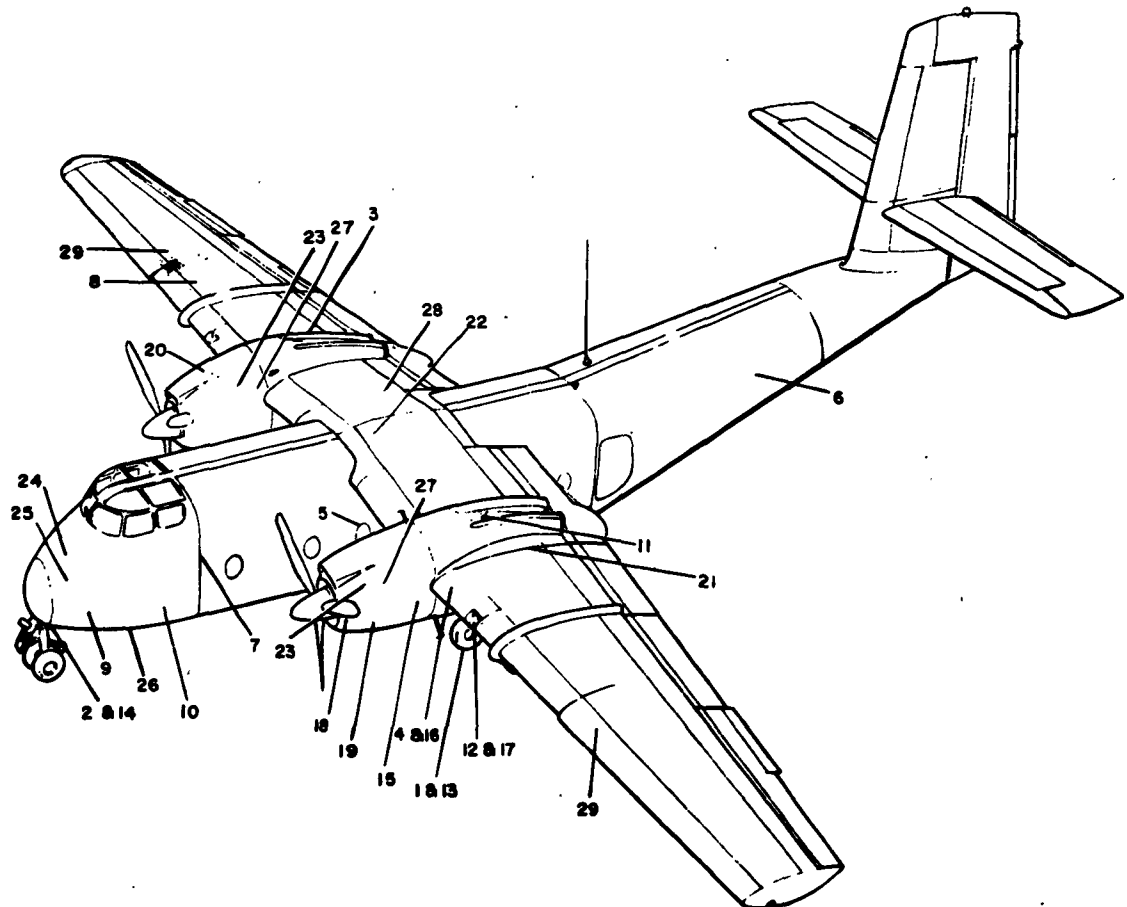


FIGURE 16. AC-1 CARIBOU SENSOR POINTS

H. Two Fuel Caps - Secured	Pt. 8
I. Left and Right Nose Access Doors - Secured	Pt. 9
J. Battery Compartment Door - Secured	Pt. 10
K. External Power - Disconnected	Pt. 11
L. Two Propeller De-Icing Tank Filler Caps - Secured	Pt. 12

Items A through J are presently a part of pre-flight and daily inspection requirement. Installation of an ALARM System would eliminate the necessity for visual inspection and provide an increased confidence level heretofore obtained only by reinspecting these areas. Propeller de-icing filler cap security is not presently inspected on the inspection list available at Bendix York. It is believed to have been inadvertently omitted.

Item K, although not called out on inspection requirements, will provide positive indication to the pilot that external power has been disconnected.

II. Continuity Channels

A. Two Main Landing Gear Weight Switches - Connected	Pt. 13
B. Nose Landing Gear Weight Switch - Connected	Pt. 14
C. Two Engine Oil Sump Chip Detectors - For Ferrous Material	Pt. 15

Items A and B are presently a part of pre-flight and daily inspection. Item C would replace post flight, daily and intermediate magnetic plug removal to inspect for ferrous material accumulation. Points 13, 14 and 15 would be inspected instantaneously by the installation of an ALARM System.

III. Liquid Level Channels

A. Two Engine Oil Tanks - Serviced	Pt. 16
B. Propeller De-Icing Fluid Tank - Serviced	Pt. 17

Item A is presently a part of all levels of inspection while item B is not called out on the inspection list available at Bendix York. Apparent omission of item B is considered an oversight on the inspection requirement.

IV. Temperature Channels

A. Two Propeller Control Units	Pt. 18
B. Two Engine Oil Scavenge Lines	Pt. 19

The two items listed above are not presently monitored directly by existing aircraft instrumentation. The propeller control oil is supplied from the engine oil system and the control contains the governor pump as well as critical bearings.

GO/NO GO monitor of these units will provide an increased safety-of-flight factor to operating personnel and aircraft.

As noted above, the engine and propeller control share a common oil supply which passes to an oil cooler and then returns to the oil tank before recirculation to the engine inlet. Engine oil temperature is monitored at the inlet and as such reflects only that the cooler is lowering the temperature of the engine outlet oil sufficiently to maintain the desired input temperature. Air flow through the cooler is controlled by shutters, thus providing compensation for the cooling effect of different ambient air temperatures as well as the engine oil return temperature. In addition, oil coolers are usually selected with BTU dissipating capabilities in excess of normal expected requirements to insure correct inlet oil temperatures under abnormal conditions. ALARM implementation is therefore recommended to provide a safety-of-flight feature by monitoring return oil temperature which reflects the internal condition of the engine.

V. Filter Bypass Channels

- | | |
|---------------------------|--------|
| A. Two Engine Oil Filters | Pt. 20 |
| B. Fuel Filter | Pt. 21 |
| C. Main Hydraulic Filter | Pt. 22 |

Implementation of the above filters would eliminate the necessity of draining the systems to examine the filter elements for foreign matter. In addition, the ALARM System would provide continuous monitoring of these flight-safety items.

VI. Vibration Channels

- | | |
|----------------|--------|
| A. Two Engines | Pt. 23 |
|----------------|--------|

Implementation of the aircraft engines with ALARM monitored velocity pickups is recommended to detect vibrations originating within the engine, propeller control, and propeller unit. Instrumentation could provide electronic evaluation of frequencies originating from propeller unbalances, gear noises in the engine, and propeller control. Monitoring of engine performance by detection of rough running and knocking which is presently detectable only by a rise in cylinder head temperature becomes possible with the addition of the ALARM System.

These vibrations are presently difficult to detect, and ALARM will provide a means of monitoring the power and propeller system condition with resulting increased flight safety.

VII. Pressure Channels

- | | |
|---|--------|
| A. Nose-Gear-Down Emergency Bottle - Air Pressure | Pt. 24 |
| B. Brakes Emergency Bottle - Air Pressure | Pt. 25 |
| C. Hydraulic Brake Air Accumulator - Air Pressure | Pt. 26 |

The above items are a part of pre-flight as well as additional inspection procedures, and implementation by ALARM would place them on an instantaneous inspection basis.

VIII. Oil Flow Channels

A. Two Engine Oil Lines

Pt. 27

Implementation of oil lines to detect leaks and abnormal oil consumption is recommended to increase flight safety and reduce inspection time. It is recognized, however, that flow rates will vary with reciprocating engine power settings and that it may be necessary to relate these settings to provide variable flow limits to the ALARM System. Further study and evaluation of reciprocating engine oil flow is strongly recommended.

IX. Other Recommended Channels

A. Fire Extinguisher Indicating Disks

Pt. 28

Two disks are provided for each of the four extinguisher systems: Left Wing and Engine, Right Wing and Engine, Cabin Heater, and Flight Compartment Heater. At each location, a yellow disk is ruptured if the extinguishing agent was expelled due to thermal overheating, and a red disk is blown out or ruptured if the system is activated manually from the flight compartment. Pre-flight inspection requires that each disk be examined to determine its condition. By use of pressure transducers or switches, inspection could be instantaneous, disks eliminated, and leaks (which would not cause disk rupture or blowout) detected as a result of low pressure since these are "One-Shot" systems.

B. Elevator and Rudder Full Travel

Monitoring is to provide the pilot with an indication that rudder and elevator are moving through their complete arcs and are not restricted by gust lock devices or improper rigging.

C. Fuel Leak Detection

New advances in the state of the art of fuel vapor detectors should be followed for possible incorporation with ALARM monitoring.

Figure 17 shows AC-1 estimated ALARM time savings.

This aircraft is not yet in sufficient use to establish average daily inspection time. TM55-1510-206-20 states that visual inspection only can be performed by one mechanic of average level in 3 man-hours (180 man-minutes).

ALARM reduces this by 49 man-minutes to 131 man-minutes as shown in the illustration.

This estimate does not include the equivalent periodic inspection time by the ALARM System to check filter assemblies and chip detectors. The instantaneous and continuous inspection reduces the periodic inspection by 66 man-minutes.

Figure 18 indicates the estimated AC-1 ALARM improved inspection effectiveness.

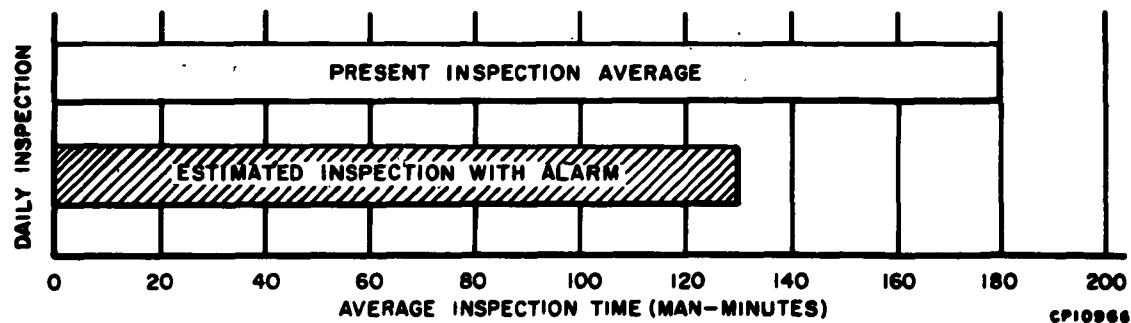


FIGURE 17. AC-1 ESTIMATED ALARM INSPECTION TIME SAVINGS

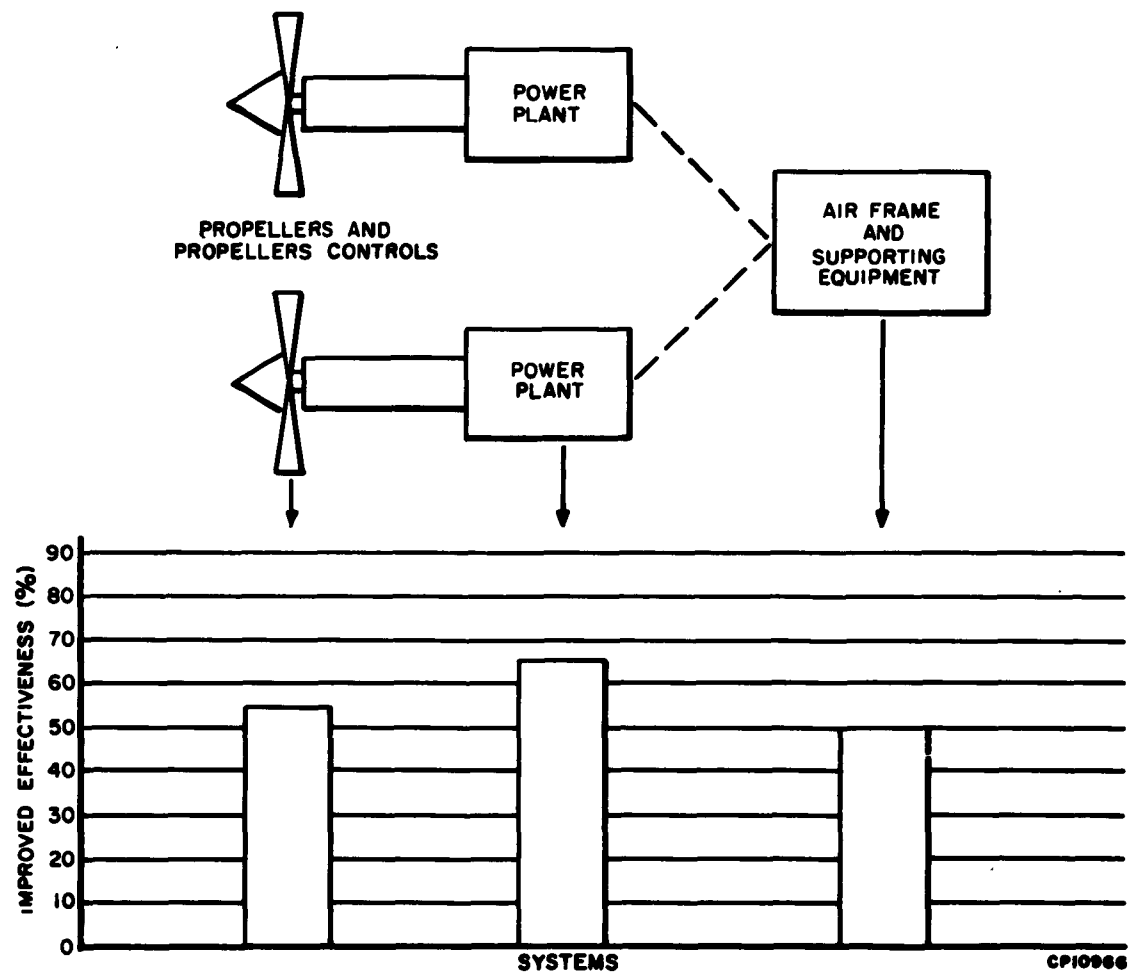


FIGURE 18. AC-1 ESTIMATED IMPROVED INSPECTION EFFECTIVENESS WITH ALARM

TABLE 6. AO-1 MOHAWK FIXED WING, ALARM APPLICATION

(Figure 19. AO-1 Mohawk Sensor Points)

I. Interlock Channels

A. Speed Brakes - Ground Safety Locks - Removed	Pt. 1
B. Ejection Seats - Ground Safety Locks - Removed	Pt. 2
C. Main and Nose Landing Gear - Ground Safety Locks - Removed	Pt. 3
D. Baggage Compartment Door - Secured	Pt. 4
E. Two Engine Cowlings - Secured	Pt. 5
F. Left and Right Aft Equipment Doors - Secured	Pt. 6
G. Hydraulic Test Door - Secured	Pt. 7
H. Top Fuel Filler Cap - Secured	Pt. 8
I. Camera Compartment Door (s) - Secured	Pt. 9
J. Two Engine Oil Tank Filler Caps - Secured	Pt. 10
K. External Power - Disconnected	Pt. 11

The above items are a part of pre-flight inspections and are recommended to reduce inspection time and provide an increased confidence factor.

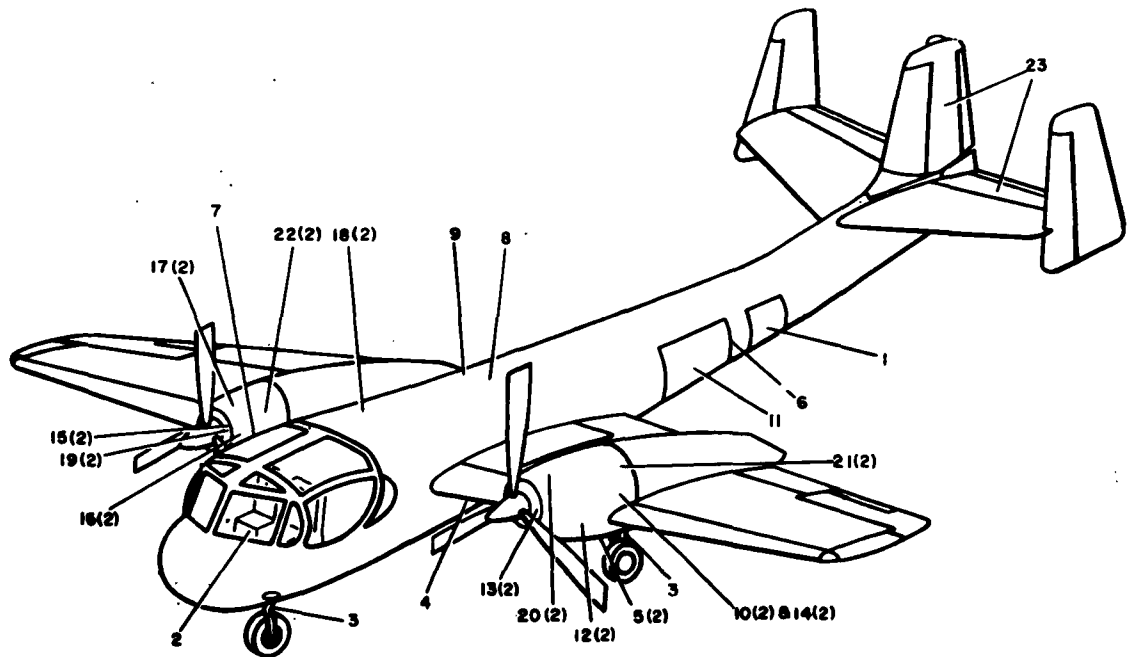


FIGURE 19. AO-1 MOHAWK. SENSOR POINTS

II. Continuity Channels

- | | |
|---|---------------|
| A. Two Engine Accessory Gear Box Chip Detectors | Pt. 12 |
| B. Two Propeller Control Oil Sump Chip Detectors | Pt. 13 |

The four locations recommended for chip detectors presently incorporate magnetic plugs which are to be removed and inspected for ferrous material accumulation at post-flight and daily inspection periods. Instrumentation by ALARM will provide instantaneous inspection, or continuous monitoring if desired, with resultant time savings and improved safety of flight.

III. Liquid Level Channels

- | | |
|--------------------------------|---------------|
| A. Two Engine Oil Tanks | Pt. 14 |
|--------------------------------|---------------|

A requirement of all inspections, but of utmost importance in pre-flight and daily, is that the tanks must be checked for proper oil levels. According to information available at Bendix York, present aircraft access for inspection of these levels is accomplished by opening the engine cowlings. This procedure would be eliminated by automatic ALARM monitoring.

IV. Temperature Channels

- | | |
|--|---------------|
| A. Two Propeller Control Units | Pt. 15 |
| B. Two Engine Oil Scavenge Lines (Oil Cooler Inlet) | Pt. 16 |

Item A and B are proposed as condition monitors of flight-safety components not presently directly instrumented.

The propeller control consists of a self-contained oil supply, valves and bearing surfaces with maximum temperatures of approximately 200°F. ALARM monitoring for this limit would provide indication of impending failure.

A sensor located on each engine oil scavenge line would give indication of internal engine operation since the oil outlet temperature of these turbine engines should not exceed approximately 300°F. Since the oil cooler heat is proportional to air flow as well as ambient air temperature, an increase in engine oil return temperature (approximately 300°F max.) could remain undetected.

V. Filter Bypass Channels

- | | |
|--|---------------|
| A. Two Engine Oil Filters | Pt. 17 |
| B. Two Main Hydraulic Filters | Pt. 18 |
| C. Two Propeller Control Main Oil Filters | Pt. 19 |

Implementation of the above items would eliminate the necessity of filter disassembly to determine if contaminants are causing oil to be bypassed around the filter elements. The fuel filters are not included in the above since pressure differential switches are already incorporated to provide indication of impending filter bypass.

VI. Vibration Channels

A. Two Engines

1. Accelerometer pick-up located in area of forward mounting pad. Pt. 20
2. Velocity pick-up located in area of rear mounting pad. Pt. 21

Two types of vibration monitoring are suggested to improve inspection and flight safety by providing detection of impending failure in the power units, comprised of the propeller and propeller control, and the Lycoming turbine engine.

The velocity pick-up is suggested to isolate low frequencies associated with propeller unbalances, fish tailing, and vibrations originating from rotating components with low rpm. The accelerometers would be used to monitor the higher frequencies and harmonics generated by gear teeth and bearing noise.

VII. Oil Flow Channels

A. Two Engine Oil Systems Pt. 22

Implementation of engine oil lines to detect leaks and/or abnormal oil consumption is recommended to increase flight safety and reduce inspection time. Preliminary study indicates the expected flow rate to be approximately 7.5 gallon per minute for this aircraft.

VIII. Other Recommended Channels

A. Elevator and Rudder-Full Travel Pt. 23

Monitoring is intended to provide the pilot with an indication that these control surfaces are moving through their complete arcs and are not restrained by gust locks or improper rigging.

Figure 20 shows the AO-1 estimated ALARM time savings. The limited number of aircraft in service indicates the average Daily Inspection time is 2.3 man-hours or 138 man-minutes. The ALARM System will reduce this to approximately 89 man-minutes. This is approximately a 36% reduction in inspection time.

The time required to inspect the filters and chip detectors during the periodic inspections will be reduced by approximately 50 man-minutes.

Figure 21 illustrates the estimated improved inspection effectiveness for the AO-1 aircraft with the ALARM System.

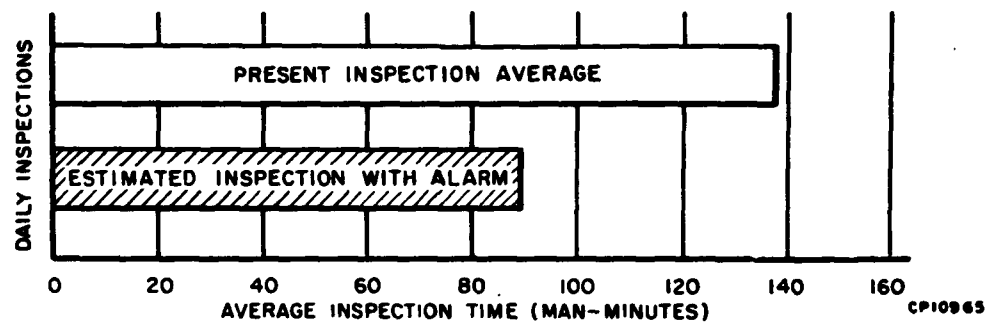


FIGURE 20. AO-1 ESTIMATED ALARM INSPECTION TIME SAVINGS

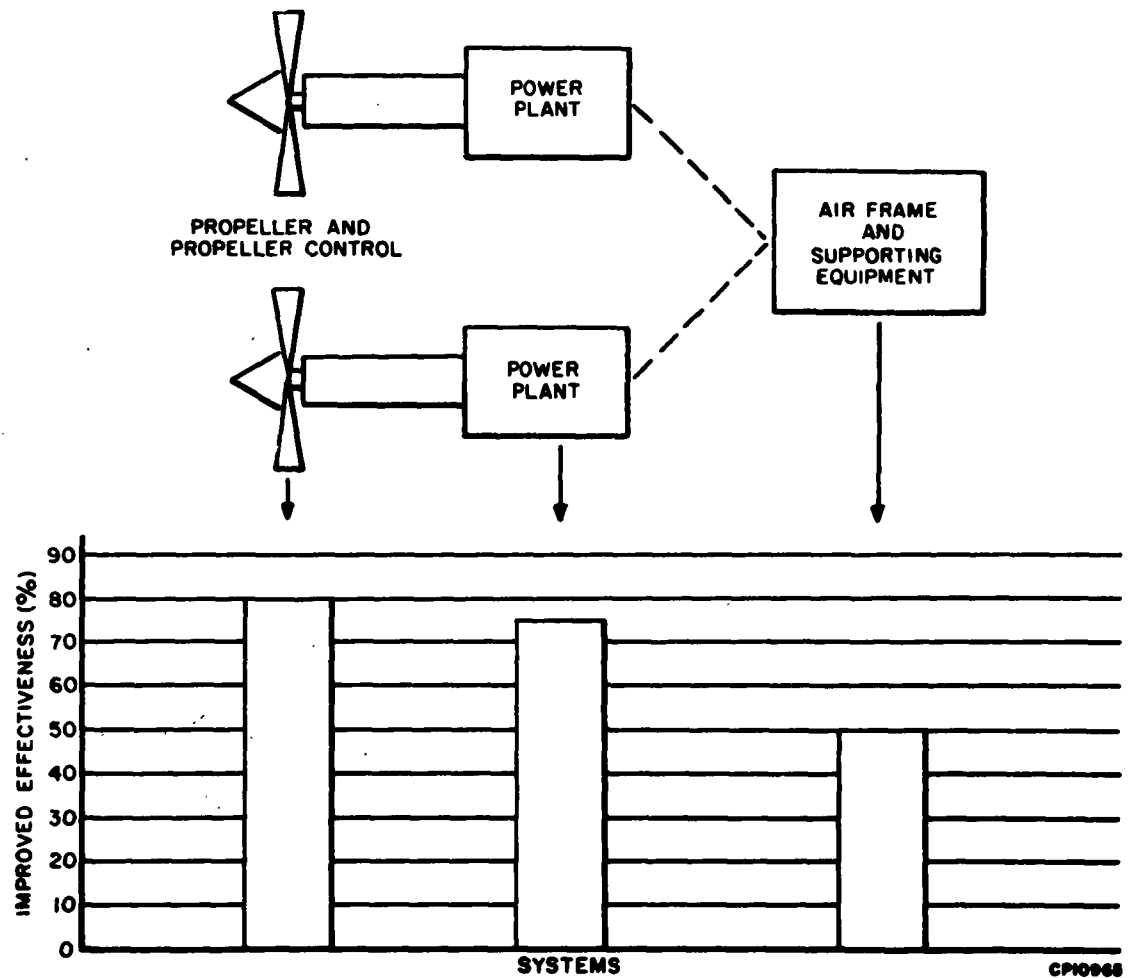


FIGURE 21. AO-1 ESTIMATED IMPROVED INSPECTION EFFECTIVENESS WITH ALARM

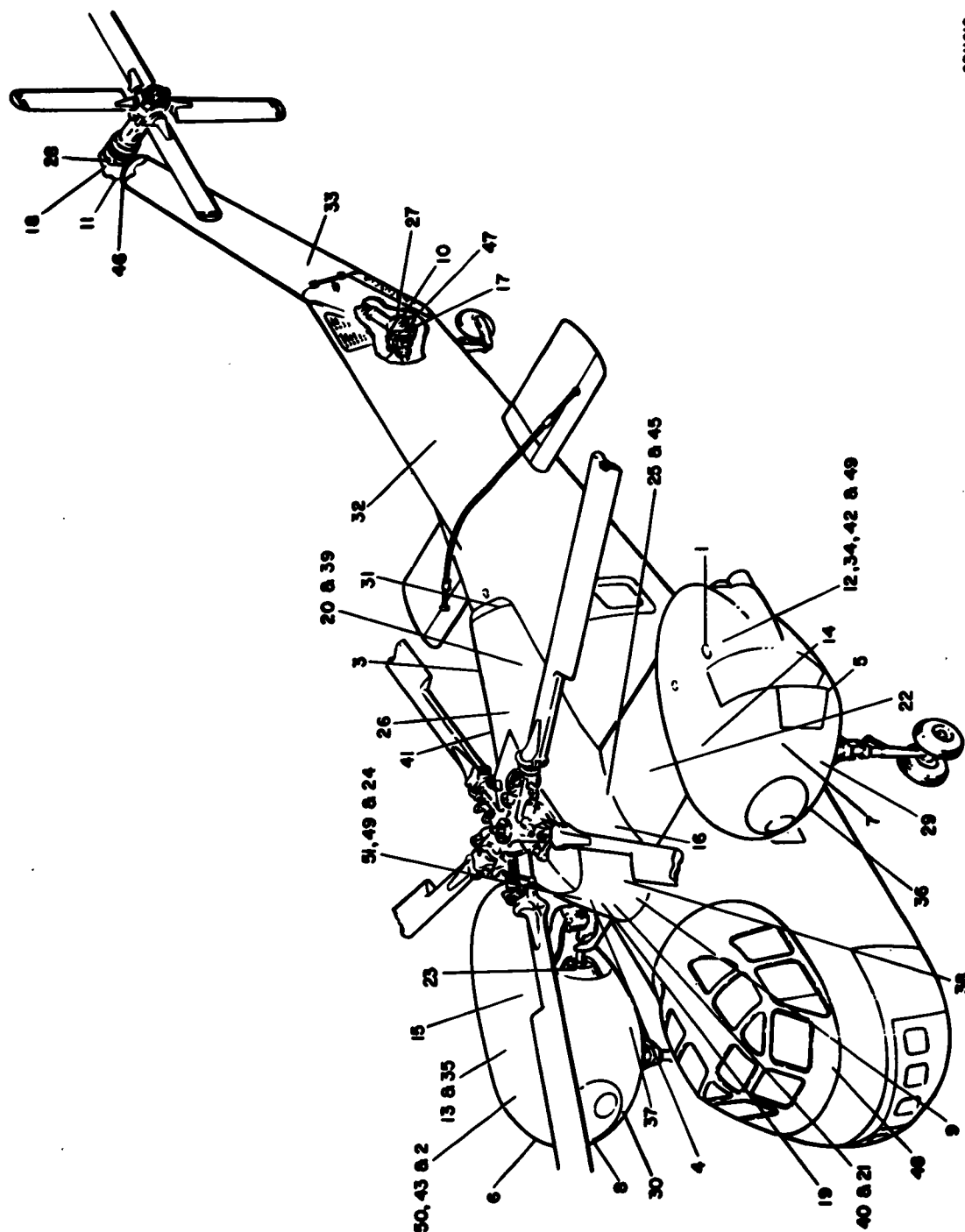


FIGURE 22. H-37 MOJAVE SENSOR POINTS

TABLE 7. H-37 HELICOPTER, ALARM APPLICATION

I. Interlock Channels

A. Left Fuel - Oil and Hydraulic Caps - Secured	Pt. 1
B. Right Fuel - Oil and Hydraulic Caps - Secured	Pt. 2
C. External Power - Disconnected	Pt. 3
D. Main Gear Box Cowlings - Secured	Pt. 4
E. Left Engine Cowling - Secured	Pt. 5
F. Right Engine Cowling - Secured	Pt. 6

ALARM implementation of the cowling and cap security is recommended to reduce inspection time. The grouping of the fuel, oil, and hydraulic caps by left and right sides will help to reduce troubleshooting time by location rather than by system.

II. Continuity Channels

A. Left Engine Magnetic Chip Detector	Pt. 7
B. Right Engine Magnetic Chip Detector	Pt. 8
C. Main Gear Box Magnetic Chip Detector	Pt. 9
D. Intermediate Gear Box Magnetic Chip Detector	Pt. 10
E. Tail Gear Box Magnetic Chip Detector	Pt. 11

Replacement of the present magnetic plugs with the chip detector is recommended to give a more complete inspection of the component as well as to reduce the inspection time to remove, inspect and replace the plugs.

III. Liquid Level Channels

A. Left Engine Oil Level	Pt. 12
B. Right Engine Oil Level	Pt. 13
C. Left Rotor Clutch Oil Level	Pt. 14
D. Right Rotor Clutch Oil Level	Pt. 15
E. Main Gear Box Oil Level	Pt. 16
F. Intermediate Gear Box Oil Level	Pt. 17
G. Tail Gear Box Oil Level	Pt. 18
H. Utility Hydraulic Oil Level	Pt. 19
I. First Stage Servo Hydraulic Oil Level	Pt. 20
J. Second Stage Servo Hydraulic Oil Level	Pt. 21

Implementation of the liquid level to the ALARM System will reduce considerably the inspection time required to determine correct oil levels. All inspections are made simultaneously and instantaneously from the cockpit.

IV. Temperature Channels

A. Left Rotor Clutch Temperature	Pt. 22
B. Right Rotor Clutch Temperature	Pt. 23
C. Main Gear Box Left Engine Input Quill Temperature	Pt. 24
D. Main Gear Box Right Engine Input Quill Temperature	Pt. 25
E. Main Gear Box Output Quill Temperature	Pt. 26
F. Intermediate Gear Box Temperature	Pt. 27
G. Tail Gear Box Temperature	Pt. 28
H. Left Engine Oil Outlet Temperature	Pt. 29
I. Right Engine Oil Outlet Temperature	Pt. 30
J. Forward Tail Rotor Drive Bearings (4)	Pt. 31
K. Middle Tail Rotor Drive Bearings (4)	Pt. 32
L. Aft Tail Rotor Drive Bearings (4)	Pt. 33

A total of 12 tail rotor drive bearings are monitored but are grouped in elements of four to conserve display area. Each bearing is monitored separately and only one bearing of the elements need be above the limit to illuminate the warning light.

The addition of these monitors will increase the flight safety aspects of the aircraft by giving an indication of component condition through temperature evaluation.

V. Filter Bypass Channels and Pressure Relief Valve Bypass Channel

A. Left Engine Oil	Pt. 34
B. Right Engine Oil	Pt. 35
C. Left Engine Fuel	Pt. 36
D. Right Engine Fuel	Pt. 37
E. Main Gear Box Oil	Pt. 38
F. First Stage Servo Hydraulic Oil	Pt. 39
G. Second Stage Servo Hydraulic Oil	Pt. 40
H. Main Gear Box Pressure Relief Valve	Pt. 41

The present filters provide no indication of clogging except on disassembly at specified intervals. ALARM implementation would place all filters on a continuous monitoring basis. The bypass relief valve in the main gear box would indicate clogged jets and possible lack of lubrication in the upper gear assembly of the gear box. These channels are added for additional flight safety, more thorough inspection, and reduction of inspection and maintenance time.

VI. Vibration Channels

A. Left Engine	Pt. 42
B. Right Engine	Pt. 43
C. Main Gear Box, Upper	Pt. 44
D. Main Gear Box, Lower	Pt. 45
E. Tail Gear Box	Pt. 46
F. Intermediate Gear Box	Pt. 47
G. Low Frequency	Pt. 48

The following characteristic vibration spectrum is anticipated:

ENGINE: Fundamental 40 to 45 cps with harmonics to the 11th order (490-510 cps) with an amplitude of ± 5 g.

MAIN GEAR BOX: 1 kc to 15 kc with a peak of 12 g at approx. 1 kc

MAIN ROTOR: Fundamentals of 5-1/2, 7, 9, 10 and 11 with ± 4 g amplitude. 20-500 cps range vary from 0.1 to 10 g.

ENGINE ACCESSORY RANGE: 20 to 500 cps with amplitudes of 0.1 to 15 g.

The addition of vibration pickups for the dynamic components will improve the inspection procedures by examination of the vibration spectrum of the bearings, gears, valves and shafts. The vibration spectrum makes it possible to detect certain type failures before they become catastrophic.

VII. Oil Flow Channels

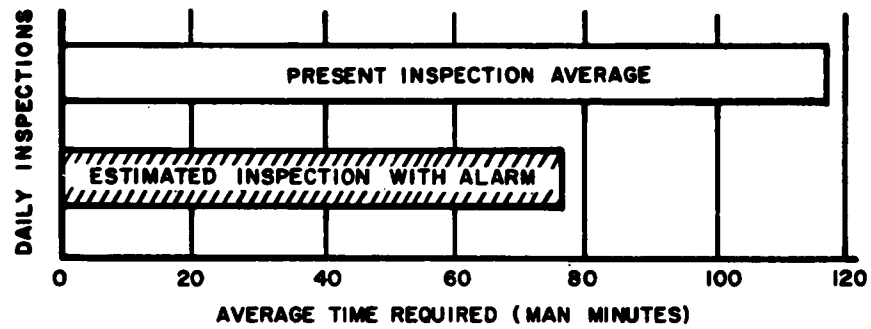
A. Left Engine Oil	Pt. 49
B. Right Engine Oil	Pt. 50
C. Main Gear Box Oil	Pt. 51

Installation of flowmeters to the oil system would provide indication of large leaks and possible excessive oil consumption. Insufficient information precludes assignment of limits.

Figure 23 shows the estimated time savings for daily inspections of the H-37 aircraft. The estimated reduction in inspection time for a daily inspection is 34%

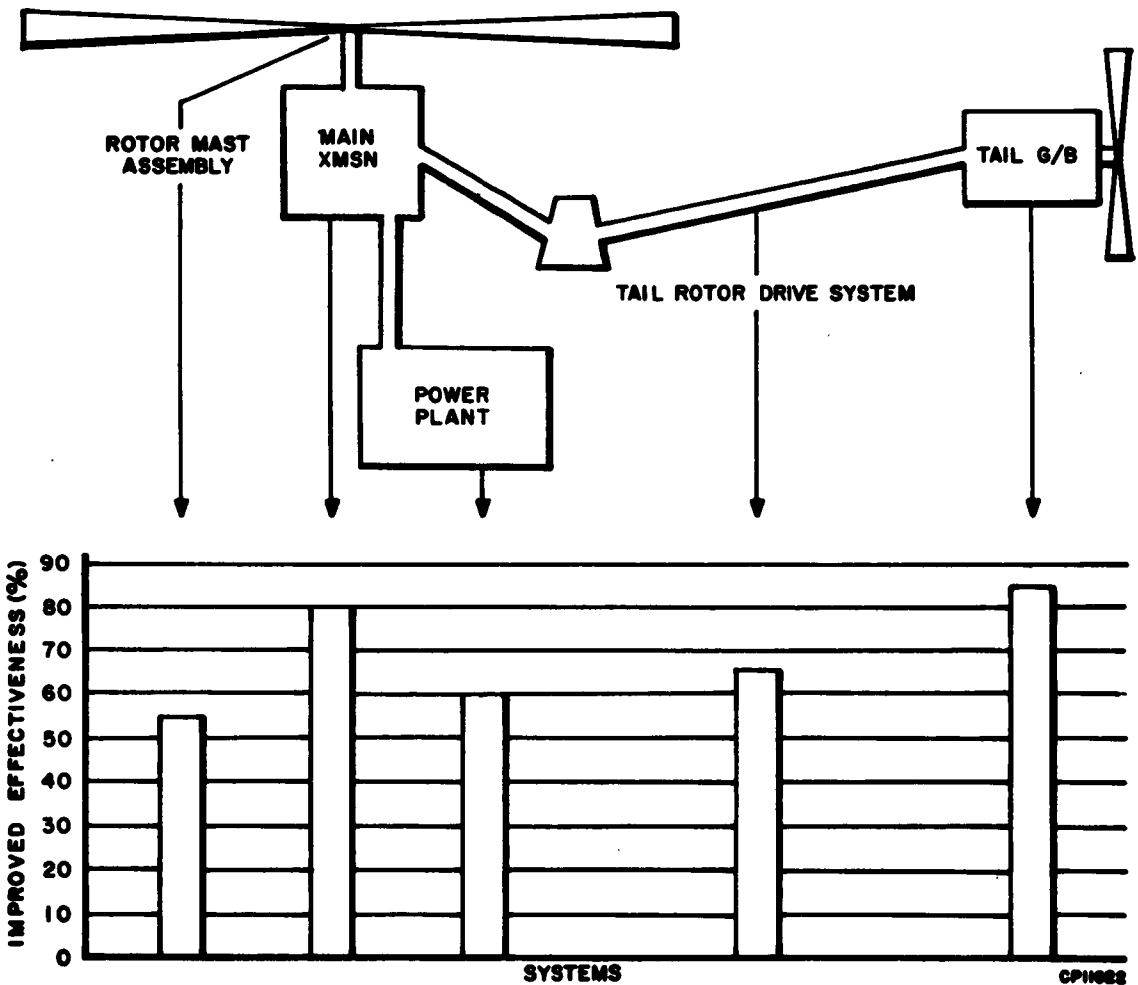
or 39 minutes from the average time of 116 minutes. Additional time would be saved during periodic inspections with the addition of the filter bypass and magnetic chip detection channels.

Figure 24 shows the estimated improved effectiveness of the ALARM System over the present inspection procedure. The aircraft is categorized by "system" since the ALARM System will be more effective in some system applications than in others.



CP11622

FIGURE 23. H-37 ESTIMATED ALARM INSPECTION TIME SAVINGS



CP11622

FIGURE 24. H-37 ESTIMATED IMPROVED INSPECTION EFFECTIVENESS WITH ALARM

SYSTEM COSTS

The ALARM System application described previously for the representative aircraft range in complexity from the 12-channel configuration for the L-19 to the 51-channel for the H-37. Estimated costs for these systems reflect the relationship of price per unit to the number of channels, primarily because sensor costs represent the major system expense.

Table 8 provides the unit price estimate for each system in quantities of 5, 10, and 15 units. In addition, the costs to install each system are provided. This installation cost includes labor and miscellaneous hardware involved in installation, but does not include any cost figures relative to travel and subsistence for personnel if installation is performed at sites other than the manufacturer's facility.

TABLE 8. SYSTEM COSTS

<u>A/C Model</u>	<u>No. Channels</u>	<u>Price/Unit (5 Units)</u>	<u>Price/Unit (10 Units)</u>	<u>Price/Unit (15 Units)</u>	<u>Installation Cost (Per Unit)</u>
HU-1	30	10,120	9,240	8,840	1,680
HC-1	42	15,970	14,600	13,950	2,350
H-13	16	5,970	5,460	5,210	900
H-23	17	6,120	5,590	5,340	950
H-37	51	18,600	17,000	16,250	2,850
AO-1	25	8,360	7,640	7,300	1,400
AC-1	28	9,020	8,240	7,890	1,570
L-19	12	4,050	3,700	3,540	670

ALARM SYSTEM VERSUS PRESENT INSPECTION REQUIREMENTS

VISUAL INSPECTION VERSUS ALARM INSPECTION

The present requirements for aircraft inspections employ a visual inspection only. Inspection tools are not used in the first and second echelon of inspection. Tools are used when maintenance is required but not during the inspection procedures. The interpretation of the inspection requirements are therefore subject to as many interpretations as there are inspectors. The variations of the interpretation may be due to the education, skill level, attitude, ability and judgement of each individual inspector. As the experience of the inspector increases, the decisions reached may tend to become more consistent with the same given set of conditions.

This basically means then that with a given condition of a component, one inspector might give a serviceable recommendation while another may give a non-serviceable decision. This is also true with the pilot when the topic is vibration. One pilot's decision would be "reject", while another would be "fly".

The use of the ALARM System to determine the condition of a component would become consistent. The ALARM evaluation of a vibration or temperature limit would remain very nearly constant. This means that for a given condition, the indication provided by the ALARM System would be very nearly constant.

A visual inspection will normally give no indication of a dynamic component's internal condition. This is particularly true of complex items such as engines, transmissions, and gear boxes. Some indication can be given through a visual inspection of a component with mechanical and visual aids. These aids would include the color stripe, magnetic plug, and filter. Inspection of these items will give a better insight to the component condition but the inspection of these items are time consuming and may not be subject to inspection when most needed. The filter and magnetic plug are normally periodically inspected items. The critical period may have passed before the inspection is accomplished.

The ALARM System provides a constant monitor of certain specific conditions within the aircraft, and the condition is visually indicated when it occurs. This condition normally will occur when the aircraft is in flight, since most of the stresses and wear occur at this time.

The ALARM System is capable of determining the variation in parameters while on the ground and is used as a ground-based piece of equipment, but much of its value is not recognized in this mode. The anticipated ability of the ALARM System to detect malfunctions before they become catastrophic would probably occur during the inflight altitude of the aircraft.

SKILL LEVEL AND PERSONNEL VERSUS ALARM REQUIREMENTS

The present skill level of personnel required to perform the inspections probably would not change. The skill level required to utilize the ALARM System would be minimal. The present concept of inspection requirements makes it mandatory to have a highly skilled mechanic perform these inspections. The addition of an ALARM System, with the same inspection requirements, will not reduce the number or skill level of personnel. However, the evolution of an inspection requirement based upon the ALARM capabilities would substantially reduce the skill level and the number of personnel required would vary with the aircraft.

The inspection of the L-19 versus the H-37 would be an example. The ALARM System would probably reduce the manpower requirements of the H-37, but since normally only one man would be responsible for the L-19 inspection, no decrease can be expected.

COMPARISON OF MAINTENANCE REQUIREMENTS

Maintenance of present inspection equipment is negative in the first and second echelon maintenance. The tools used for maintenance are simple in nature and the most complex would be the electrical multimeter. Maintenance of the multimeter would probably require a calibration check every three to six months. Abuse of the equipment would require additional maintenance. Repair work would require the services of the third and fourth echelon instrument maintenance group with personnel trained for MOS 295.2 (Electronic Instrument Repairmen).

Maintenance of the ALARM System is in the same general category but is more complex. Regular maintenance is recommended at six-month intervals for calibration of the sensors and calibration of the various ALARM control circuits. Repair work on the ALARM System would require personnel trained for MOS 295.2 (Electronic Instrument Repairmen).

Maintenance for the ALARM System becomes slightly more complex than the current maintenance system since the calibration of the sensors will require removal and reinstallation from the aircraft. Advancing state of the art in sensor reliability would improve sensor calibration requirements from the present recommendation of six months to annual calibration.

FLIGHT SAFETY COMPARISONS

Utilizing an ALARM System will increase the flight safety of aircraft by indicating malfunctions as they occur rather than determining the malfunction after the aircraft is out of service. No statistics were available to determine the discovery rate of malfunctioning dynamic components on the ground versus the discovery by failure in flight. A good estimate would probably be that for every gear box, transmission, or engine found to be defective during inspection on the ground, one would be found during flight which would require emergency procedures. The major portion of dynamic component failures now is detected during flight by aural or tactile methods ("it doesn't sound right", "doesn't feel right", or "doesn't handle like it should").

The ALARM System has proven certain malfunctions can be detected long before the aircraft operator is aware of the condition. (TRECOM Technical Report 63-10 Volume I, II & III). Tests were conducted while the test aircraft was on the ground, but it is felt even more dramatic results can and will be obtained during flight.

RECOMMENDED MILITARY SPECIFICATIONS

The following Military Specifications pertinent to ALARM System application are recommended. In addition, reference should be made to Bendix Engineering Specification No. 1129982, Automatic Light Aircraft Readiness Monitor (ALARM), provided in TRECOM Technical Report, 63-10, Volume II, dated January 1963, pages 117 through and including 125 (Appendix VI).

MIL-E-7080A	Electric Equipment, Piloted Aircraft Installation and Selection of, General Specification For
MIL-STD-704	Electric Power, Aircraft, Characteristics and Utilization of
MIL-STD-16B	Electrical and Electronic Reference Designations
MIL-STD-15A	Electrical and Electronic Symbols
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MIL-E-22436	Electronic Assemblies, General Specifications For
MIL-E-5400E	Electronic Equipment, Aircraft, General Specification For
MIL-E-19600A	Electronic Modules, Aircraft, General Requirements For
MIL-E-21981	Electronics Type Designations, Identification Plates & Markings, Requirements For
MIL-STD-446	Environmental Requirements for Electronic Component Parts
MIL-E-5272C	Environmental Testing, Aeronautical and Associated Equipment, General Specification For
MIL-C-172C	Cases, Bases, Mounting, and Mounts, Vibration For Use With Electronic Equipment in Aircraft
MIL-C-3885A	Cable Assemblies & Cord Assemblies, Electrical For Use In Electronic, Communication, and Associated Electrical Equipment
MIL-C-27500	Cable, Electrical, Shielded & Unshielded, Aircraft, & Missile
MIL-F-25381	Flight Testing, Electric System, Piloted Aircraft & Guided Missile, General Requirements For
MIL-F-7179A	Finishes and Coatings, General Specifications for Protection of Aircraft & Aircraft Parts
MIL-T-7775	Test Assembly, Electric Power Equipment, Aircraft, General Specification For

MIL-STD-202B	Test Methods for Electronic & Electrical Component Parts
MIL-T-6780	Test Procedure for Electrical Installation in Aircraft
MIL-T-18303	Test Procedures, Preproduction & Inspection, For Aircraft Electronic Equipment, Format For
MIL-T-945A	Test Equipment, For Use With Electronic Equipment, General Specification
MIL-C-45662	Calibration of Standards
MIL-STD-174A	Color Coding for Electronic Parts
MIL-H-5475B	Handbook, Operation Electronic, Electrical, Electro-Hydraulic, and Electromechanical Equipments, Systems & Test Equipment
MIL-I-45208	Inspection Requirements, General Specification For
MIL-I-8700	Installation & Test of Electronic Equipment In Aircraft, General Specification For
MIL-I-5997A	Instruments & Instrument Panels, Aircraft Installation Of
MIL-I-5949D	Instruments, Flight & Engine, Aircraft, Functional Tests & Tolerances Of
MIL-M-16616	Manual, Technical, Electronic Equipment
MIL-M-7911	Marking, Identification of Aeronautical Equipment Assemblies, & Parts
MIL-R-26667A	Reliability & Congenuity Requirements, Electronic Equipment, General Specification For
MIL-S-6872A	Soldering Process, General Specifications For
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